NOISE AND HEARING:

A STUDY OF LOOM NOISE AND HEARING LOSS IN A POPULATION OF FEMALE JUTE WEAVERS

by

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FOREWORD

A Letter to my Brothers Carl and Johann
Beethoven, on the Subject of DEAFNESS

"For the last six years I have been afflicted with this incurable complaint made worse by incompetent doctors. Though endowed with a passionate and lively temperament and even fond of the distractions offered by society, I was soon obliged to seclude myself and live in solitude. I could not bring myself to say to people 'speak up, shout for I am deaf'. I refer to the impairing of a sense which in me should be more perfectly developed than in other people, a sense which at one time I possessed in the greatest perfection. I must now live quite alone and creep into society only as often as sheer necessity demands. If I appear in company I am overcome by a burning anxiety, a fear that I am running the risk of letting people notice my condition. How humiliated I have felt if somebody standing beside me heard the sound of the flute in the distance and I heard nothing - such experiences made me despair and I was on the point of putting an end to life - the only thing that held me back was my art. For indeed, it seemed to me to be impossible to leave this world before I had produced all the works that I felt the urge to compose".

Ludwig van Beethoven,
Heiligenstadt,
October 6th, 1802.

THIS THESIS IS DEDICATED TO THE JUTE WEAVERS OF DUNDEE. THEY ACCEPT A HEARING IMPAIRMENT DUE TO THEIR WORK ENVIRONMENT WITHOUT COMPLAINT OR RESENTMENT. THEY OVERCOME THEIR HEARING HANDICAP BY VARIOUS ADAPTATIONS OVER A LIFE TIME OF EXPOSURE TO LOOM NOISE AND THEY REPRESENT A GENERATION, NOW RAPIDLY DISAPPEARING, OF INDUSTRIOUS, LOYAL AND HAPPY PEOPLE.

SUMMARY

In the City of Dundee, Scotland, between 3,000 and 4,000 employees are occupationally exposed to the noise of jute weaving machinery. The looms have been installed since 1892 and, but for a change in drive from belt to independent electrical motors, the noise of the looms is likely to have been constant for over 60 years. In addition, the weaving population, being predominantly female, and not subjected to other types of noise such as shooting, is remarkably stable, with long weaving service, in some cases over fifty years in the same weaving shed and even at the same loom. It seemed desirable to study this population before the noise and the stability altered.

The objectives were:

(a) to define the noise stimulus by means of noise instrumentation and oscilloscope,

(b) to measure the deterioration of hearing by pure tone audiometry, with years of noise exposure as the main parameter,

(c) to compare the weavers hearing levels with those of a population not exposed to industrial noise - the control population of Dundee school teachers. The hypothesis to be tested is that there is a positive association between occupational hearing loss and duration of noise exposure.

(d) knowing the hearing levels as a function of exposure time, to compare the hearing losses with the degree of

social disability as measured by questionnaire.

(e) to make certain proposals relating to overall noise levels in industry.

The clinical work carried out in the course of this work, from 1962 to 1967, involved otological examination and pure tone audiometric measurements of thirty-two jute office workers, 296 school teachers and 401 weavers. In addition, fifty-seven weavers plus four controls were examined by pure tone audiometry and a questionnaire completed, designed to assess the degree of social impairment. Thus, the experimental work covers a total of 790 subjects.

In order to estimate the loss of hearing due to noise, it has been assumed that the difference between the recorded hearing level and, (a) that of the non-noise exposed teacher in the same age group, or (b) Hinchcliffe's non-noise exposed rural population in Scotland, represents the deterioration due to occupational exposure. Of the two statistical treatments used, the teacher control pair comparison showed higher initial loss in the weavers due to the fact that the Dundee school teachers showed better hearing than the British Standard. In both treatments, the initial deterioration in hearing is high and continues to be rapid in the first ten to fifteen years, followed by a period of twenty years where the hearing loss curve flattens. This type of saturation curve is found at the 4000 and 3000 cps frequencies. The 2000 cps curve proceeds by two steps similar to that found by Glorig in America.

When the hearing losses, following a loom noise exposure of 35 years and upwards, are examined by the American method of averaging the losses at the three frequencies 500, 1000 and 2000 cps, then 50% (Q2 Quartile) of the original sample of weavers are in the "impaired" zone defined by the American Academy of Ophthalmology and Otolaryngology. Examination of the 45 to 52 years of loom noise exposure (number of ears - 90) shows that 25% (Q3 Quartile) of the sample are at or above the limit where practical aid is required by amplification. Thus, the study has given some indication of the consequences of a lifetime of weaving exposed to loom noise of 100 dB SPL.

In 1967, two sheds of obsolete looms were replaced by new looms with double the pick speed. Noise levels rose from 99 - 100 dB to 102 - 103 dB. From the data presented here, it is likely that hearing losses will, in the future, be even higher, in particular in the speech frequencies 2000 and 3000 cps.

The desirability of controlling the noise energy emitted from new machinery installations is discussed. Responsibility for hearing conservation programmes, in view of the rising noise levels, falls within the sphere of the industrial physician, and must include pre-employment and serial audiometry. A view is, however, expressed that a positive preventive measure would be to introduce now legislation whereby loss of hearing due to noise becomes, as in several other countries, a Prescribed Industrial Disease, thus recognising that noise causes a loss of hearing faculty. The data presented here strongly support this view.

HISTORICAL INTRODUCTION AND REVIEW

A HISTORICAL INTRODUCTION and REVIEW

The Age of Noise : it is a label which fits our times and there are few who could not compile a list of sounds both annoying and deafening. Yet, because the effects of noise, especially on hearing, are insidious, they tend to be accepted as part of the price to be paid for living in the 1960's.

Loss of Hearing due to noise is not a new discovery. One of the earliest cases of loss of hearing due to a noisy occupation is that of Quasimodo, the hunchback bellringer of Notre Dame, described by Victor Hugo in a novel relating events in the year 1482. Centuries later, Bernardino Ramazzini, the father of Occupational Medicine, included in his review of the health of the arts and trades [1] the bakers of bread. "What so necessary to life as bread-making? Among their health hazards - heat, hard work during the night and sleeping all day like bats in the constant noise of wheels and millstones and the roar of water falling from a height, so that they are nearly always hard of hearing; for the eardrum is continually struck with too violent an impact and loses its tonus". In this work, Ramazzini also describes the main disease of copper-smiths, "The ears are injured by a perpetual din so that workers of this class become hard of hearing and if they grow old at this work, completely deaf". There is evidence that Ramazzini was aware of noise-induced deafness in Egyptian times in his reference to the Egyptians living on the banks of the Nile [2] "For they are all deaf from the excessive uproar of the falling water". In Sweden, Nils Skragge in a thesis on Morbi Artificum in 1765 wrote "Coppersmiths (Cupranii) usually become hard of hearing as a result of the hammer blows".

Fosbrooke [3] in 1830 published "Pathology and Treatment of Deafness" and in 1831 drew attention to the frequent occurrence of deafness among blacksmiths. Once deafness became established, vertigo was a frequent symptom. In 1881, Gorstein and Keyser [4] found that of seventy-five blacksmiths and machine workers, 40% were hard of hearing and only 39% had normal hearing. Early in the 19th Century, it was also noticed that riveters and workers hammering inside boilers suffered in some cases severe impairment of hearing, to such an extent that the term "boiler-makers' deafness" was coined. In 1886, Barr [5] in a paper remarkable for its research content, without elaborate instrumentation, stated, "It is familiarly known that boiler-makers and others who work amid very noisy surroundings are extremely liable to dullness of hearing. In Glasgow we would have little difficulty in finding hundreds whose sense of hearing has thus been irremediably damaged by the noisy character of their work". In 1907, Wittmaack and Siebenmann [6] published a report on the histology of noise-induced deafness, the first attempt to explain why and where the loss of hearing occurred and the first experiments on the inner ear of animals exposed to noise. In 1908, Bezold and Siebenmann [7] described noise as the most frequently occurring cause of neuro-sensory or perceptive deafness. An important Dutch publication by Van Waveren [8] described in 1924 the so-called "gunners' deafness" in navy personnel.

Attention was first drawn to textile weaving as a cause of occupational deafness when McKelvie [9] in 1933 published an investigation into cotton weavers' deafness. One-third of 1011 weavers investigated were found to have a measurable degree of hearing loss. It is of great interest to note that, without sophisticated instrumentation, these authors reached a conclusion that weavers suffered fairly severe impairment only if they had been exposed to loom noise for more than ten years. Eight years later the Ministry of Health Research Board produced two further studies on cotton weavers in 1932 [10] and 1935 [11] by Weston and Adams. In these reports the emphasis was laid on work performance and efficiency of the operators as distinct from the hazard of hearing impairment due to loom noise. For a time, therefore, interest in the auditory effects of noise lapsed following the findings of Weston and Adams (subsequently disproved) that with a noise intensity of 96 decibels, the output of weavers was lowered by 3% compared with a control group weaving in a noise environment of 81 decibels. Their results, at that time indicated that loom noise was an important factor influencing and determining individual working efficiency. In these now classical reports on weavers, the first observations concentrated on the psychological effects of noise, to the exclusion of the auditory effects and even suggested that the development of partial deafness appeared to protect against "irritation", "annoyance" and "distraction". This is the earliest reference to "acclimatisation" or "adaptability", a process by which consciousness of the subjective effects of noise becomes less, whether due to partial deafness or central nervous system effects. In these early Weston and Adams reports, in the absence of electronic equipment, measurement of hearing of weavers was noted by a method in common use at that time and used in previous hearing studies, namely determining whether a forced whisper could be heard at a distance of twenty feet.

The 20th Century ushered in the "noise age". Engines and machines already present in the latter half of the 19th Century were speeded up. The invention of the internal combustion engine was quickly followed by its introduction into motor cars and then into ships and aeroplanes, so that noise was now produced on land, sea and air. A Belgian medical officer, Gilbert (12) noting the rising noise levels in 1921, pleaded for an International Board of Physicians to be set up to investigate and assess noise hazards within places of employment, with powers of entry. He insisted that hearing loss, due to a high level noisy environment, should not only concern otologists but be regarded as an industrial hygiene problem - a remarkably prophetic and far-seeing recommendation, not yet adopted in Britain today, but now accepted in fifteen countries in the world.

The hearing tests of Barr, Weston and Adams, and Gilbert were performed with meagre equipment. The spoken and whispered voice tests were followed by watch-ticking and tuning forks. Nevertheless, by the 1930's, the majority of workers had concluded that in subjects exposed to noise:

(a) the sensitivity of air conduction was reduced,

(b) air conduction was better than bone conduction - a positive Rhinne test pointing to an inner ear or perceptive-loss type of deafness, and

(c) the hearing loss was severest at the higher frequencies.

No further progress was made until the development of the audiometer - an electronic device for the precise production of pure tones at known, variable intensity levels. It now became possible, by means of these new instruments to carry out hearing surveys on large industrial populations more accurately than ever before. As a result of the new data obtained from industrial surveys, Fowler [13] in 1927 became the first man to associate hearing loss in the 3000 to 4000 cps frequency region of the audiogram with exposure to industrial noise. This significant finding was soon confirmed by many authors, including Bunch [14] in 1937 and from this time onwards the loss of hearing in the 3000 to 4000 cps region became known as the C_5 dip or the 4 kc notch and characteristic of a noise-induced hearing pattern. The shape of the audiogram thus became a valuable diagnostic aid in the differential diagnosis of deafness. An example of a noise-induced audiogram is shown in Figures 2 and 3, with a normal audiogram for comparison (Figure 1) and a normal audiogram with the age factor (presbycusis) present (Figure 1A).

From 1935 onwards, society as a whole gradually became aware of the harmful effects of exposure to high level noise, whether in the auditory or psychological fields. The widespread interest in noise resulted from a combination of several factors:

(a) the increasing number of work personnel exposed to noise,

(b) the transfer of responsibility for an occupational disability from the worker to employer, already accomplished in Britain for most traumatic injuries and occupational diseases,

(c) the technological advances, both in the field of

DEPARTMENT OF SOCIAL AND OCCUPATIONAL MEDICINE, DUNDEE

Patient's name: I.U. Age 22 Test date

Occupation SECRETARY No. of years in noise NONE

Pure tone air conduction audiogram

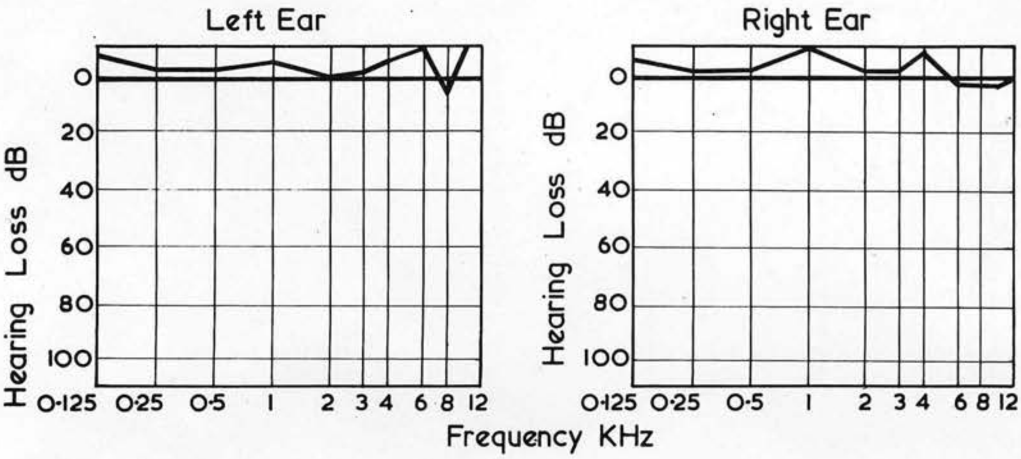

Fig. 1 : NORMAL AUDIOGRAM

DEPARTMENT OF SOCIAL AND OCCUPATIONAL MEDICINE, DUNDEE

Patient's name: W. T. Age 55 Test date JULY 1967

Occupation LECTURER No. of years in noise NONE

Pure tone air conduction audiogram

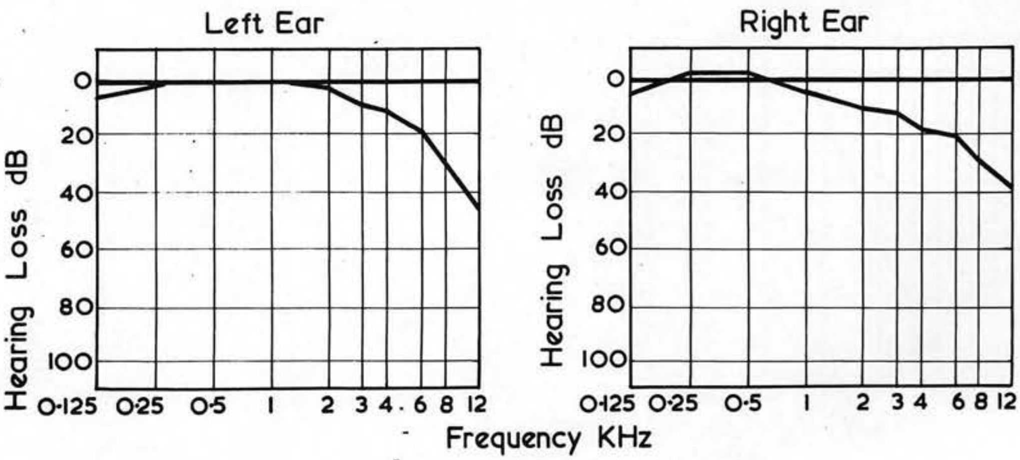

Fig. 1A : LOSS OF HEARING DUE TO AGE (PRESBYCUSIS)

DEPARTMENT OF SOCIAL AND OCCUPATIONAL MEDICINE, DUNDEE

Patient's name: MRS. E.M. Age 59 Test date

Occupation WEAVER No. of years in noise 41

Pure tone air conduction audiogram

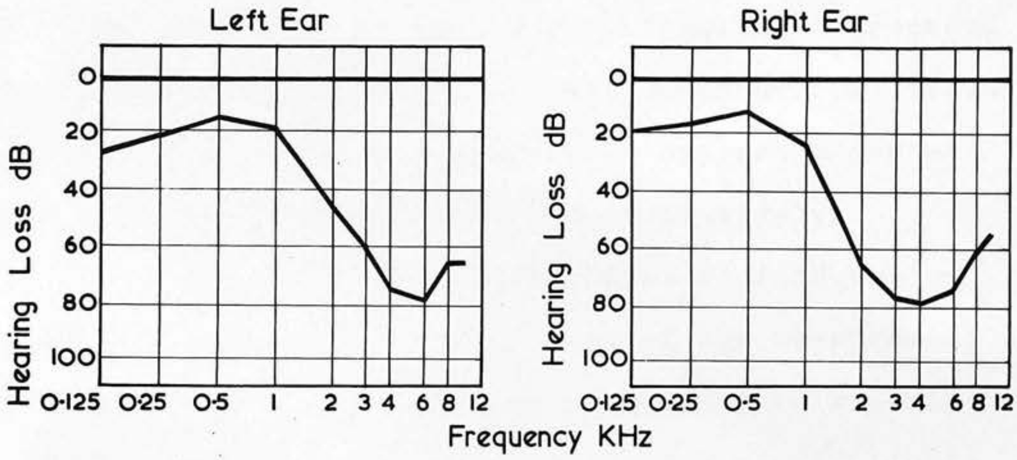

Fig. 2 : EXAMPLE OF NOISE-INDUCED HEARING LOSS - 41 YEARS EXPOSED TO WEAVING NOISE

DEPARTMENT OF SOCIAL AND OCCUPATIONAL MEDICINE, DUNDEE

Patient's name: T. W. K. Age 62 Test date

Occupation COAL GRADING No. of years in noise 30

Pure tone air conduction audiogram

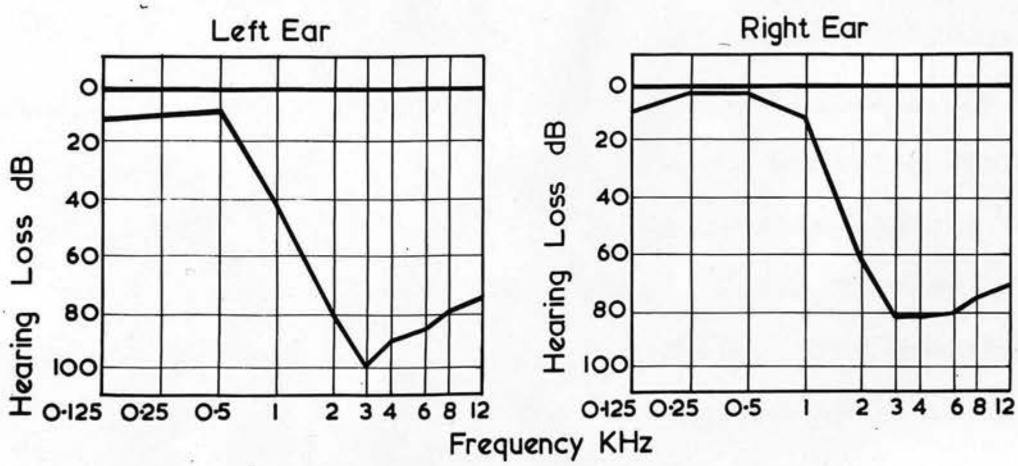

Fig. 3 : EXAMPLE OF NOISE-INDUCED HEARING LOSS - 30 YEARS EXPOSED TO COAL GRADING MACHINERY

noise measurement and audiometry,

(d) the increasing knowledge in the field of medical statistics and a clearer understanding of the epidemiological approach to mass surveys.

Rapid improvement in the techniques of noise measuring equipment in the 1950's, enabling a spectrum analysis to be carried out as well as an overall sound pressure level, made it feasible to express a man's noise environment and exposure quantitatively.

It is not surprising, therefore, to find the pendulum swinging in the direction of the measurement of hearing impairment, as opposed to subjective experimentation, with the sole object of producing reliable, clinical hearing loss data. At some future date it was hoped that the mass data so obtained might be used to define limits and regions above which legislation might be introduced, and compensation recognised for loss of hearing. Large numbers of surveys were published at this time, including ship builders, (Larsen [15] 1939), aviators (Dickson et al [16] 1939, Campbell [17] 1942, Dickson [18] 1939), submarine personnel (Schilling [19] 1942), shoe, cleaning brush factories and printing works (American Academy of Ophthalmology and Otolaryngology [20] 1957). The United States Public Health Service in 1953 and 1954 [21,22] obtained data relating hearing acuity and long-term exposure to industrial noise in male weavers. The deafness of weavers attracted much attention from research workers in many countries, including Atherley [23] 1962 in England, Kristensen [24] 1946 in Denmark, Copplestone [25] 1959, and Rodda et al [26] 1963 in New Zealand. Cox et al [27] from America, pointed the way to controlled surveys in a prospective study on noise and audiometric histories resulting from cotton textile operations. Burns et al [28] in 1964 found, in a longitudinal study over three years, significant shifts in weavers at 2000 and 8000 cps exposed to weaving noise with an overall SPL of 100 dB. In a population of male and female weavers, the degree of noise-induced persistent threshold shift due to weaving over a period of ten years was of the order of 15 dB at 2000 cps and 40 dB at 4000 cps.

In these and subsequent studies it became clear that there were many experimental difficulties in defining precise standards and in attempting to correlate hearing loss with noise exposure. Those recognised were:

(1) It was difficult to define noise exposure with respect to duration, noise intensity and continuity of exposure. In particular, the character of the noise, whether continuous or impact, had a bearing on the hearing loss, in that impact noise, where the wave form showed a fast rise time, was found to be more damaging than continuous noise.

(2) Individual susceptibility was a factor, the

distribution of hearing loss in a noise exposed population following a normal or Gaussian pattern as in other biological phenomena.

(3) Changes in hearing level were either of a temporary or a permanent nature and it was necessary to provide noise-free intervals of at least 36 hours [29] before the temporary loss factor could be excluded.

(4) In assessing hearing impairment due to noise, allowance had to be made for a normal ageing process - presbycusis.

(5) Extraneous noise of a non-occupational origin, such as hobbies, for example, shooting, had to be excluded.

(6) There were problems of organisation, handling large industrial populations without disrupting production within factories. This aspect was acute if audiometric measurements were confined to a time interval 6 a.m. to 7.30 a.m. on a Monday morning prior to the shift commencing and immediately following a noise-free weekend.

(7) Although the instrumentation for hearing measurement had been improved technically, yet two problems still remained, namely fundamental calibration to a known standard and the variation or "drift" of the electronic circuitry and head-phones between six monthly calibrations.

(8) Audiometry must be carried out in a known low-

noise level environment which was difficult to find in or near factories.

(9) A clinical assessment of the population must be carried out at the same time as the audiometry to exclude ear pathology, drugs, etc. Wax, where present, would require to be removed.

Between the 1950's and 1960's, therefore, research workers in this field became aware of the large number of uncontrolled variables present in so-called "hearing surveys", the main object of which was to assess the hearing impairment resulting from known exposure to a known noise.

HISTORY AND OBJECTIVES OF THE DUNDEE STUDIES

History and Objectives of the Dundee Studies

Dundee had been associated with the textile industry for more than four hundred years, at first with woollens and subsequently with hemp and flax. In 1527 Hector Boece wrote: "Dundee, the town quhair we wer born, quhair mony virteous and lauborious pepill ar in, making of claith" - in this case plaiding. In the mid-18th Century there was a considerable expansion of the linen industry, with flax cultivation in the district covering many thousands of acres, and large quantities of flax being imported from the Baltic. By 1800 the port had also developed into a whaling station. By 1839 experiments using jute fibres to replace flax were successful, using 10% of whale oil added to the fibre to enable a continuous fibre to be spun with the required tensile strength. The jute industry, thereafter, expanded very rapidly, until today, 93% of the jute spinning spindles and 75% of the jute weaving looms in Britain are to be found within the City of Dundee and its suburbs. The total estimated population (Registrar General, 1965) was 185,296 and of this total, 17 to 18,000 are engaged in jute processing, and of these, from 2 to 3,000 are exposed to loom weaving noise.

Between World Wars I and II a modernisation programme was undertaken by the jute trade in Dundee, with the main emphasis on preparing and spinning in the mills. In the factories, however, where waft and weft fibres are woven into cloth in the process of weaving, development had been slow and until the recent introduction of "broad loom" weaving, loom design had remained static for seventy to eighty years.

The Dundee female jute weavers were thus thought to present an ideal research population for a retrospective hearing survey for the following reasons:

(a) The weaving population was predominantly female and this population was not therefore exposed to extraneous noise, as for example found in a male population in this area (shooting and wild fowling in the Tay Estuary).

(b) The female weavers present a stable population with remarkably long and continuous employment, in many instances up to fifty years in the same weaving shed and on the same loom.

(c) There was also available a smaller population of retired weavers, now on pension, with a complete, continuous, working life exposed to loom noise.

(d) The loom noise in certain weaving sheds has been constant since the looms were manufacfured more than seventy years ago, with one alteration through conversion from steam power to electric drive. It thus seemed desirable, before the jute weaving process became modernised with a complete transition to large looms and possibly to man-made fibres, to take advantage of a stable, female population not exposed to extraneous noise and with known durations of exposure to one type of noise, the physical characteristics of which are also known and which have remained unaltered with reasonable certainty for over seventy years.

There was no noise data (either overall Sound Pressure Levels or spectrum analyses) available for jute looms, due to the mixed nature of the noise spectrum. On empirical grounds, the spectrum was thought to be a mixture of impact and continuous noise. One reason for the lack of noise data was the inherent limitations of the noise-measuring instrumentation, in particular the means of accurately measuring the impact component due to shuttle and pick-arm impacts. It was necessary, therefore, to define the loom noise characteristics as accurately as the audiometer measurements in attempting to correlate noise exposure and hearing loss.

IN SUMMARY, THE OBJECTIVES OF THIS STUDY ARE:

(1) To measure overall Sound Pressure Levels (SPL in decibels re 0.0002 μbar) found in jute processes and to analyse the noise into its component tones or octave frequency bands. In particular, to define loom noise characteristics.

(2) To measure the hearing level of a population of female jute weavers exposed to loom noise, according to years of loom noise exposure.

(3) To measure the hearing level of a similar age and sex matched population not subjected to industrial noise but exposed to normal city noise. A population of Dundee school teachers was chosen as the control population.

(4) To investigate the relationship between the duration of exposure to noise and occupational hearing loss estimated by the difference between the weaver-teacher pairs. The hypothesis to be tested is that there is a positive association between duration of noise exposure and occupational hearing loss.

(5) To define the hearing loss on a social disability scale and thus attempt to define weaver disability for future legislation.

(6) To plan a hearing conservation programme for Dundee textile weaving operatives with particular reference to young weavers, the main object of which is to prevent the onset of occupational deafness.

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Glossary of ACOUSTICAL TERMS

British Standard 661 : 1955 defines the fundamental acoustical terms used in the fields of Acoustics and Medical Research on Hearing. Throughout this thesis, the following terms have been used with the meanings appended:-

(1) SOUND - A mechanical vibratory phenomenon transmitted through an elastic medium as a train of alternating variations in pressure which may be represented as a sine wave. The mechanical disturbance excites the sensation of hearing.

(2) NOISE - Sound which is undesired by the recipient. It usually consists of complex unrelated frequencies. Since it involes an emotional response on the part of the listener, it is a subjective sensation.

(3) SOUND PRESSURE - The alternating component of the pressure at a point in a sound field. The unit is the dyne per sq. cm. The reference level for noise measurement is 0.0002 dynes per sq. cm. and is the reference against which all sound level meters and noise analysing equipment are calibrated.

(4) THE DECIBEL - The decibel is a ratio of two sound pressures and so is dimensionless.

The denominator of this ratio is the above sound pressure reference level, namely 0.0002 dynes per sq. cm. Measuring sound level meters and noise analysing equipment are scaled in decibels all to the above reference, and hence the unit, the decibel, means the same throughout the world. When the decibel scale is applied to audiometers, however, the denominator is the sound pressure threshold of hearing value which will vary with frequency. Therefore, the decibel scales on sound level meters and audiometers are not directly comparable.

(5) <u>FREQUENCY</u> - Frequency is the rate of repetition of the cycles or waves on the elastic medium (air). There are several methods of expressing frequency:

(a) The basic unit is the cycle per second (cps).

(b) When the scale is multiplied by 1000, the unit is the kilocycle per second (kc/s).

(c) A new term for frequency has now been introduced (1967), namely Hertz which includes the time factor per second and has been introduced as a monosyllabic term for convenience.

(d) When the scale is multiplied by 100, the new term is kilohertz.

Throughout this thesis, frequency has been expressed as cps, except when space does not permit multiplication by 1000, when kc/s has been used, especially in graphs and drawings. An attempt has been made in the latter part of the thesis to conform to the new standard by using the term Hertz.

(6) LOUDNESS and PITCH - These subjective terms have not been used in this work.

(7) SOUND LEVEL - The Sound Level is a weighted (by using appropriate filters such as the "A" network) value of the sound pressure level as determined by a sound level meter.

(8) PURE TONE - The audiometer or instrument for the measurement of the threshold of hearing employs test tones of constant frequency, i.e. a tone in which the sound pressure varies sinusoidally with time. This physical stimulus when applied through earphones (or by loud speaker) gives rise to the sensation of hearing.

(9) BAND PRESSURE LEVEL - The sound pressure level of the sound energy within a specified frequency band.

(10) OCTAVE BAND PRESSURE LEVEL - The band pressure level for a frequency band corresponding to a specified octave.

(11) <u>THRESHOLD OF HEARING</u> - The minimum r.m.s. value of the sound pressure of a sinusoidal sound wave of that frequency which excites the sensation of hearing.

(12) <u>NORMAL THRESHOLD OF HEARING</u> - The modal value of the thresholds of hearing of a large number of otologically normal observers between 18 and 25 years of age.

(13) <u>AUDIOGRAM</u> - A graph or chart relating hearing loss for pure tones to frequency.

SECTION 1 MEASUREMENT OF LOOM NOISE

Fig. 4 B & K Sound Level Meter

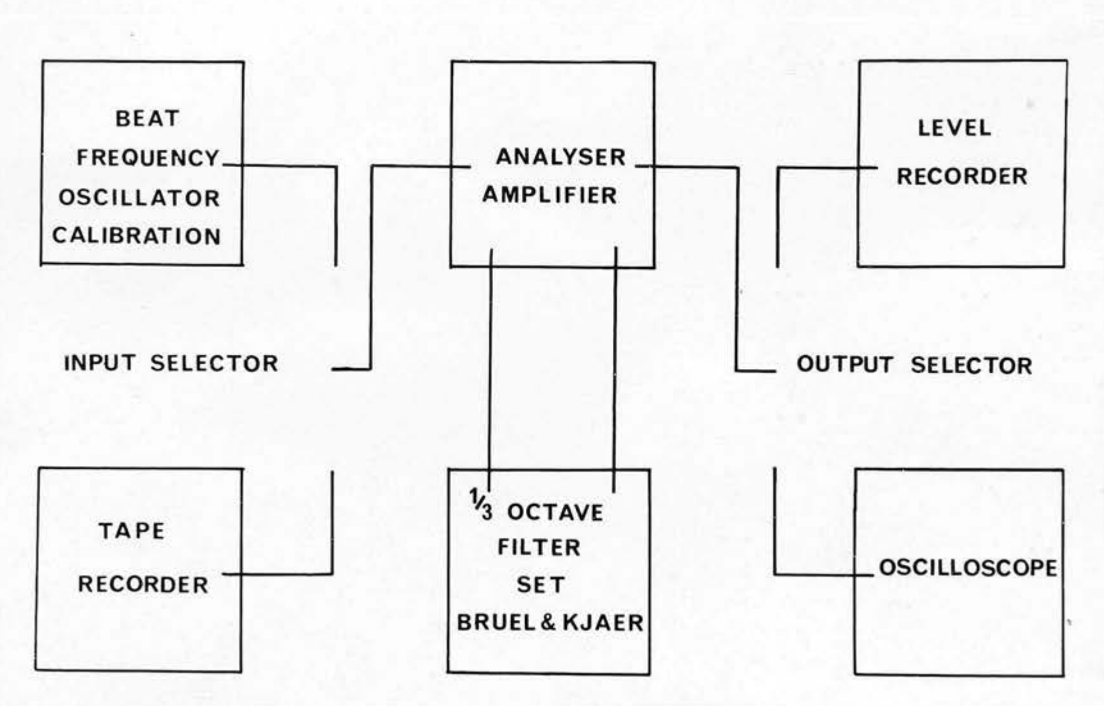

Fig. 5 Block Diagram. Test Equipment

SECTION 1 : MEASUREMENT OF LOOM NOISE

A. Apparatus

Throughout the noise surveys, Bruel and Kjaer sound measuring equipment has been used. Overall sound pressure levels (SPL re 0.0002 microbar) and octave band width analyses were made with the B. and K. meter type 2203 (Figure 4) with the octave filter set 1613 attached. In the analysis of weaving noise in particular, where impact noise components are present due to the action of the shuttle, band-pass $\frac{1}{3}$ octave filter set (Type 1612) and a narrow band frequency analyser (Type 2107) were used, together with a direct writing sound level recorder (Type 2305). For the accurate determination of impact peaks, an oscilloscope was used. For research purposes accurate basic calibration is essential and for this purpose the B. and K. Pistonphone Calibrator (Type 4220) was used with the sound level meter and the Beat Frequency Oscillator (Type 1013) for detailed frequency analyses, when the measuring equipment was set up as in the block diagram (Figure 5).

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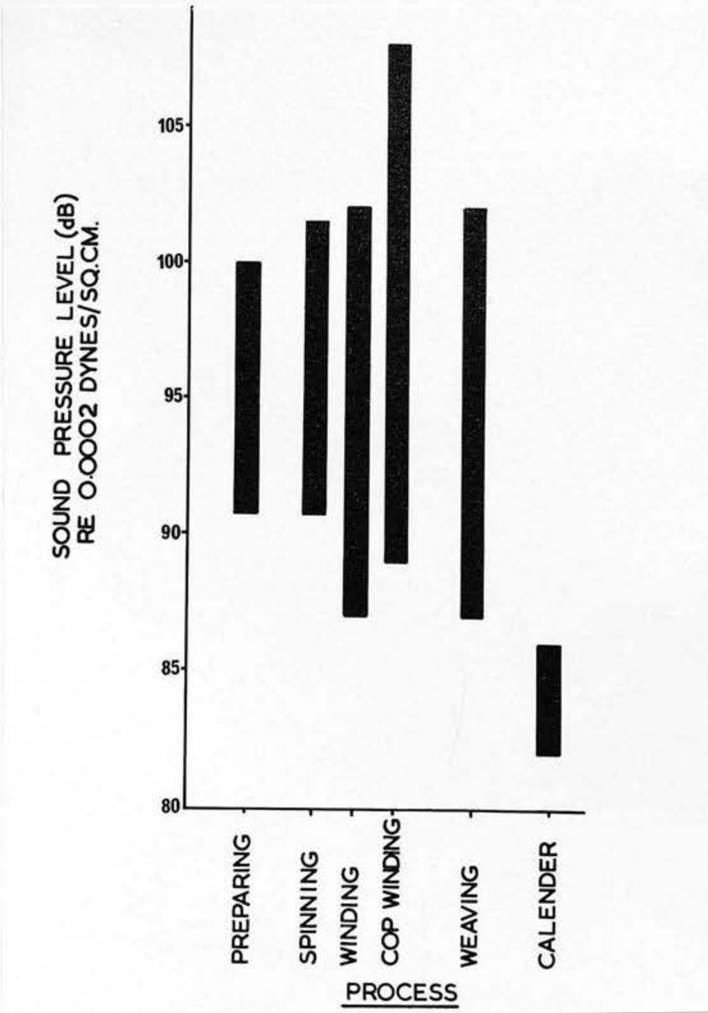

Fig. 6 S.P.L. Values Jute Process

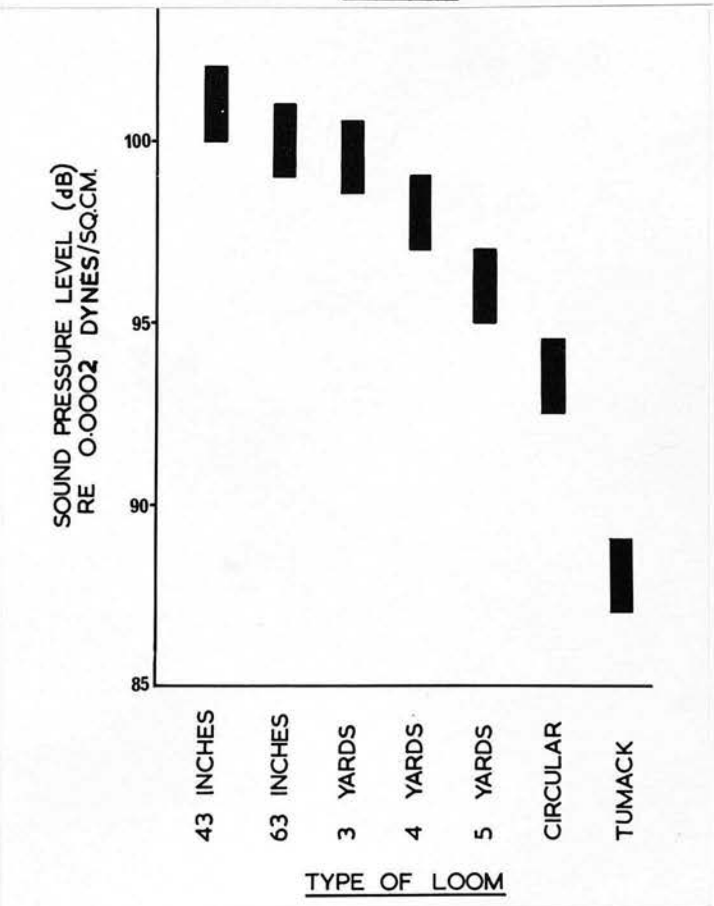

Fig. 7 S.P.L. Values in weaving areas with different loom types.

and for every make and size of weaving loom. In addition, $\frac{1}{3}$ octave and narrow band analyses were made in the loom passes and at the weavers' rest seats in the narrow loom (43 inches and 63 inches) section. Finally, by means of the oscilloscope, detailed analyses were made of the narrow loom (43 inches and 63 inches) noise.

C. Results of Noise Surveys and Analyses

The surveys of noise in jute processing (i.e. preparing, spinning, winding, cop winding, weaving and calendering) showed a wide variation of SPL values even in the same process in different mills and factories (Appendix, Tables 1 to 5) and Figure 6. In general, it has been found that there are wide variations in machines designed for the same purpose, making allowance for differences in the factory surroundings, height of roof, material of boundary walls etc. The accepted level for hearing conservation is in the region of 90 dB (or 85 dBA scale) overall SPL for the frequency characteristics found by octave band analyses. It will be seen that, allowing for the large variations found in the various factories (of the order of 20 dB), all jute processing is on or above the maximum criteria, with the exception of the calender or finishing processes.

The weaving process also displayed a wide range of

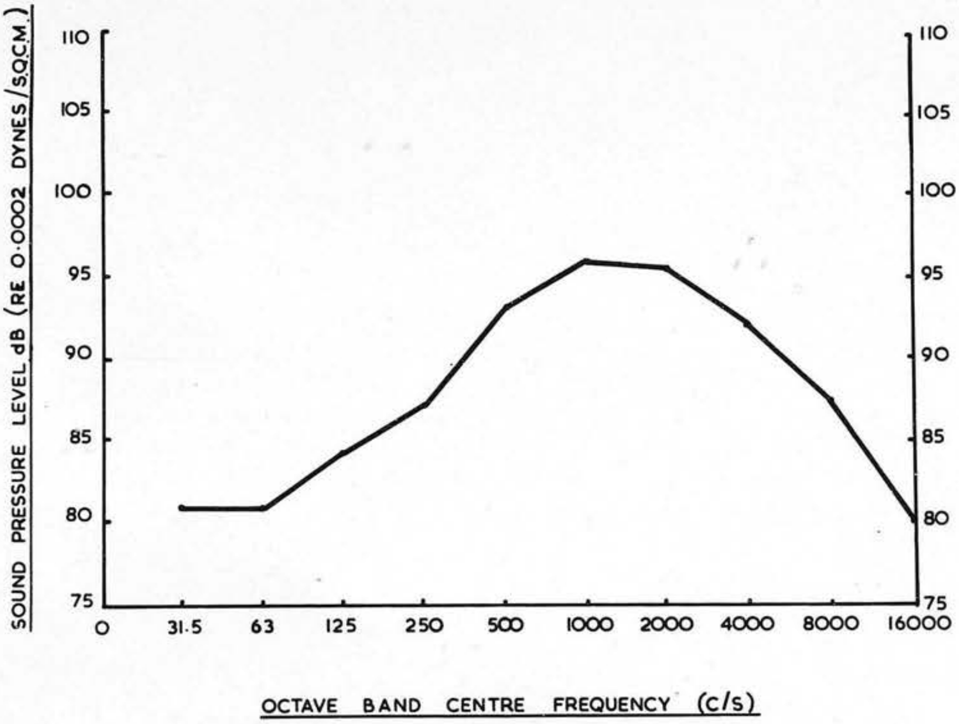

Fig. 8 Octave Band Analysis
Noise in areas occupied by 43 and 63 in. looms

Fig. 9 Narrow Band Analysis - 43 and 63 in. looms
Selectivity at 3 dB bandwidth is 6%

overall values, but these were found to be highly dependent on loom size and type (Figure 7). In all weaving sheds, irrespective of building contours, roof height and pitch, the narrow (43 inches and 63 inches width) flat, overpick type, overall SPL values of 99 to 102 dB were found at the work position and measured with the slow damping characteristic of the sound level meter. The noise is of a wide band continuous type, Figure 8 (octave band) and Figure 9 (narrow band). The frequency spectrograms obtained on the level recorder (Figure 9) showed peaks of the order of 8 to 10 dB corresponding to the shuttle impacts from the traditional weft-insertion system used on these seventy-year old looms. Oscillo-scopic examination, however, when instrument inertia is reduced, reveals transients of peak amplitude of the order 15 to 18 dB above the mean noise level of 99 to 101 dB because of both the shuttle and picking arm impacts. The rise time of the impacts is of the order o.25 m.sec. The rate of impact does not exceed 18 sec. (Figure 10) and therefore, it is not considered that weaving noise has a true impact component. [1] The frequency component of the impacts in these narrow 43 inches and 63 inches jute looms has been found to be about 1600 cps.

Earlier investigations had indicated that the major sources of high impact noise were the shuttle-accelerating and decelerating mechanisms superimposed

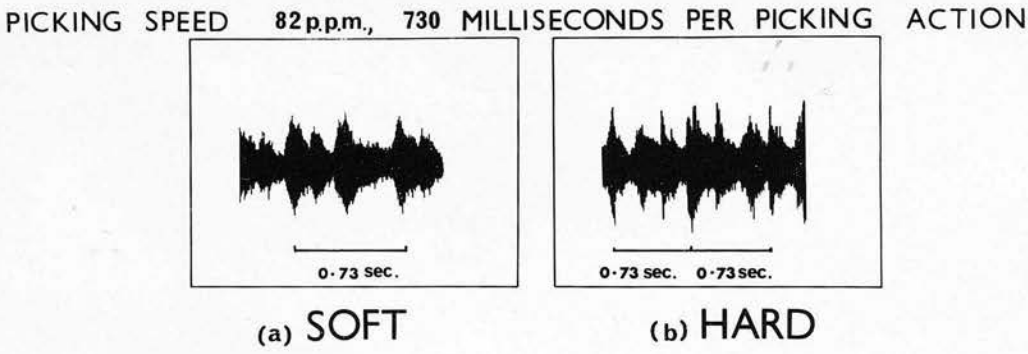

Fig. 10 Peak Values for loom fitted with soft and hard picker

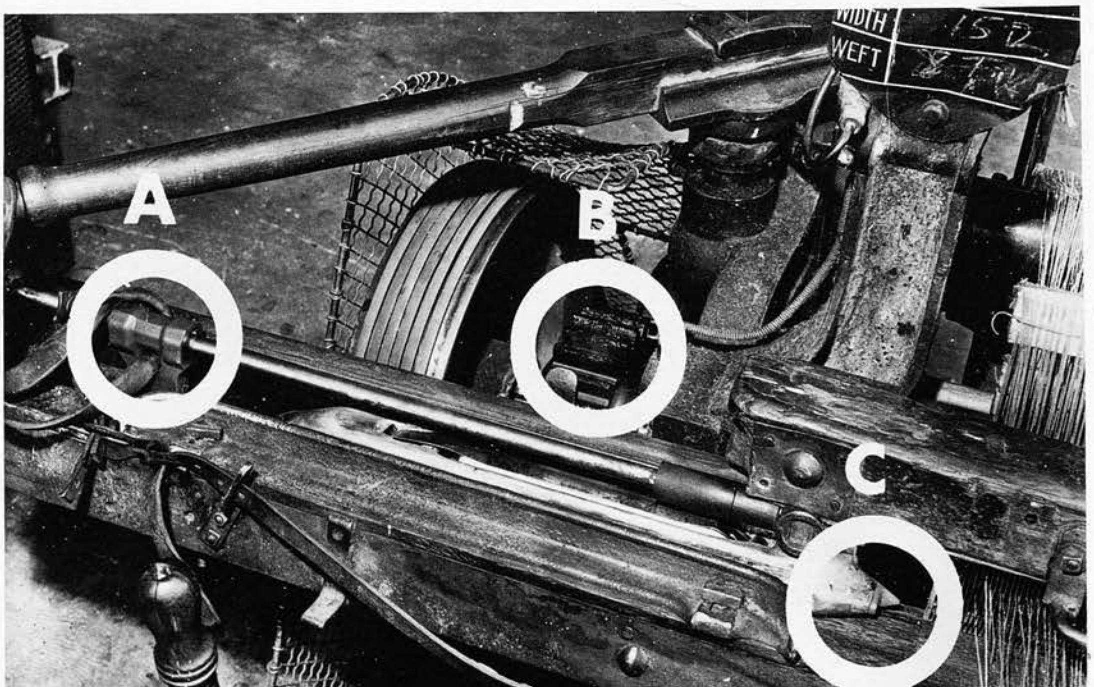

Fig. 11 Components of loom responsible for high impact noise

on a background of gear and reciprocating-motion noise. Three of the relevant components are depicted in Figure 11.

(A) picker actuated by a picking stick,

(B) the crank-shaft pinion through which the drive to the slay is transmitted, and

(C) the metal shuttle tip.

More recent attempts have been made (Taylor et al [2]) on a 4 yard overpick loom, to reduce the impact components and detailed noise measurements were repeated at various stages of assembly, concluding with the fully operational loom weaving jute fabric. This procedure was repeated on the same loom in the same environment, plastic parts being substituted for metal. The results were disappointing; the noise reduction achieved by the substitution of plastic components being of the order of 2.0 dB limited to the frequency range 0.5 to 2.0 kc/s. A greater noise reduction was achieved by substituting a soft picker (polyurethane) for the normal hard picker (polyethylene), the maximum reduction being of the order of 3.3 dB.

D. <u>Weaving Noise - Noise Intensity Data relating to Present Study</u>

In order to make an accurate assessment of the noise environment and the duration of noise exposure, it was decided, following the results of the surveys of the ten jute mills and factories, to confine the investigations to weavers operating narrow, flat, overpick looms, sizes 43 inches and 63 inches. It is not possible to give a single noise intensity figure for the exposed population, but from the results, an overall SPL of 100 ± 2 dB covers the measured variation and is representative of this type of jute loom. This value is in line with published data [(3)] although it is possible with the longer, heavier shuttle used in jute processing as opposed to cotton, that the impact component is considerably higher in jute. The noise in the narrow loom passes and at the rest stools and in the area of the weavers' ears is notable for its narrow range (± 2 dB). The spectrum shows maxima in the octaves centred at 1000 and 2000 cps. The female weavers chosen for this study have been restricted to those operating narrow looms, the noise characteristics of which, it is reasonably certain, have not altered within the last seventy years.

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SECTION 2 MEASUREMENT OF HEARING

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A. The Standard Normal Threshold of Hearing (British Standard)

The pure-tone audiometer measures the deviation (in decibels) of a subject's threshold of hearing from an arbitrary standard chosen to represent so-called "normal hearing". In pure-tone threshold audiometry the subject listens to an electronically generated pure tone which is adjusted in intensity, by an external operator (manual audiometry), until the auditory threshold is determined. Since the sensitivity of the ear varies with frequency, the test must be done at a number of selected frequencies and each ear is done separately. Thus it is necessary to standardise audiometers for the different frequencies to a given set of threshold values representing reference levels - in this experimental work, to British Standard - based on the results of the British Standards Institute 2497 (1954) [1], British Standard 2980 (1958) [2] supported by subsequent work of Hinchcliffe [3], Knight and Coles (1960) [4]

B. Audiometer Calibration

A Peters clinical audiometer Type SPD/2 with TDH-39 telephones and MX41/AR cushions was used throughout this work, adjusted to conform to British Standard, with the tolerances specified in B.S. 2980. With this instrument it is possible to monitor the output of the oscillator (but not the output stages) and thus, adjust if necessary, the voltage and frequency before audiometry of each individual subject. Throughout the period of study (1962 to 1967) the electrical output of the instrument showed no significant change. Changes, however, of the order of 0.5 to 3.0 dB did occur in the telephones. Basic calibration of the Peters audiometer was carried out at six to eight-monthly intervals by an independent laboratory [5] in Glasgow. In the early stages of the experimental work, five subjects (office workers) with normal hearing were used as daily controls as a check for gross malfunction of the output stage and telephones. In the final two years of the study, weekly calibration checks for drift were made with a B. and K. artificial ear attached to a B. and K. sound level meter. The calibration checks indicate that changes did occur between the six-monthly calibrations, which may have introduced unknown variations of the order of ± 1.5 dB relative to British Standard.

In summary, therefore, the maintenance of the calibration standards or the "drift" of the audiometer, whether in circuit or telephones, proved to be one of the most difficult variables to control over the five year period. The variation was dependent on the make of audiometer, and two unsatisfactory instruments in early experiments were discarded before finally settling on the Peters SPD/2 for extended measurements. The planned objective was to measure the hearing of two populations, namely the teacher control group and the jute weaver population on the same instrument by one operator (W.T.) the instrument being calibrated to British Standard and held at this response level for a period of five years.

C. <u>The Technique of Hearing Measurement</u>

The pure-tone air conduction audiometry was performed throughout by the method recommended by Littler [6] at frequencies of 125, 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 cps in steps of 2.5 dB. For diagnostic purposes, 10,000 and 12,000 cps were done at the same time, but the errors incurred, both in audiometer calibration and in positioning the MX41/AR cushions on the subjects' ears, were of the order ± 10 to 12 dB and these two frequencies were not, therefore, used in the statistical analyses. In hearing loss due to noise, however, the audiogram usually shows a distinct rise (that is, less hearing loss) at the upper end, and the shape is thus an indication that the loss is due to noise and not to ear pathology. To reduce errors due to possible variation between right and left ears, audiometric measurements were made, alternating right and left earphones. The terminology used here will be that of Davis, Hoople and Parrack (1958).[7] <u>Hearing Loss</u> signifies the symptom of reduced auditory sensitivity. It is synonymous with partial deafness. <u>Hearing Level</u>

is an index of the status of a person's hearing. It states the difference in dB between the minimum sound intensity perceptible by the person, that is, the auditory threshold and the normal auditory threshold specified by the particular standard of hearing which is used.

D. The Audiometric Environment

The investigation of hearing in industry presents certain technical difficulties. For example, it is not practicable to convey factory employees long distances for audiometric examination and thus, in common with other industrial field studies, the minimum interference with production is essential, both from the point of view of management, and more important, to obtain a high percentage volunteer rate in the region of 90% and above. Audiometric investigations must therefore be made as near as possible to work places. Experience has shown that in factories which are themselves usually intrinsically noisy, it is difficult to find a room where a commercially available audiometric booth would provide internal sound pressure levels suitable for audiometry. Many of these problems can be met by the provision of a sound-insulated audiometric vehicle, either as a self-contained motorised unit or as a trailer which is towed to the factory and placed in a suitably quiet environment in the factory precincts. The commercial type booth is thus permanently erected within the trailer, the whole forming a double chamber.

Various mobile audiometric vehicles have been designed, for example, the Royal Canadian Air Force [8] (1946), Sullivan and Hodges [9] (1952) and Lee et al [10] (1963). These designs varied considerably and the cost factors also showed wide variation. In the case of the vehicle built for the school teacher and weaver population surveys the main objectives were:

(a) low initial cost (£700 to £800),
(b) the ability to accommodate a commercial audiometric booth,
(c) small size to reach suitable sites within jute mills,
(d) the attenuation of ambient sound should be enough to measure normal hearing as defined in A, whilst situated in the external ambient noise of jute mills

The vehicle had to be sufficiently warm and habitable to operate in the conditions of a Scottish winter. These objectives were satisfied by a simple rectangular enclosure mounted on a two-wheeled trailer chassis containing the commercial booth mounted on resilient mountings. The design of the shell had to be such that, in ambient noise with a frequency spectrum of the type shown in Figure 12, the attenuation of shell plus that of the commercial booth had to be sufficient to measure the hearing of all young people without auditory impairment.

The critical acoustic conditions for audiometry frequently occur at the lower frequencies, namely, 125,

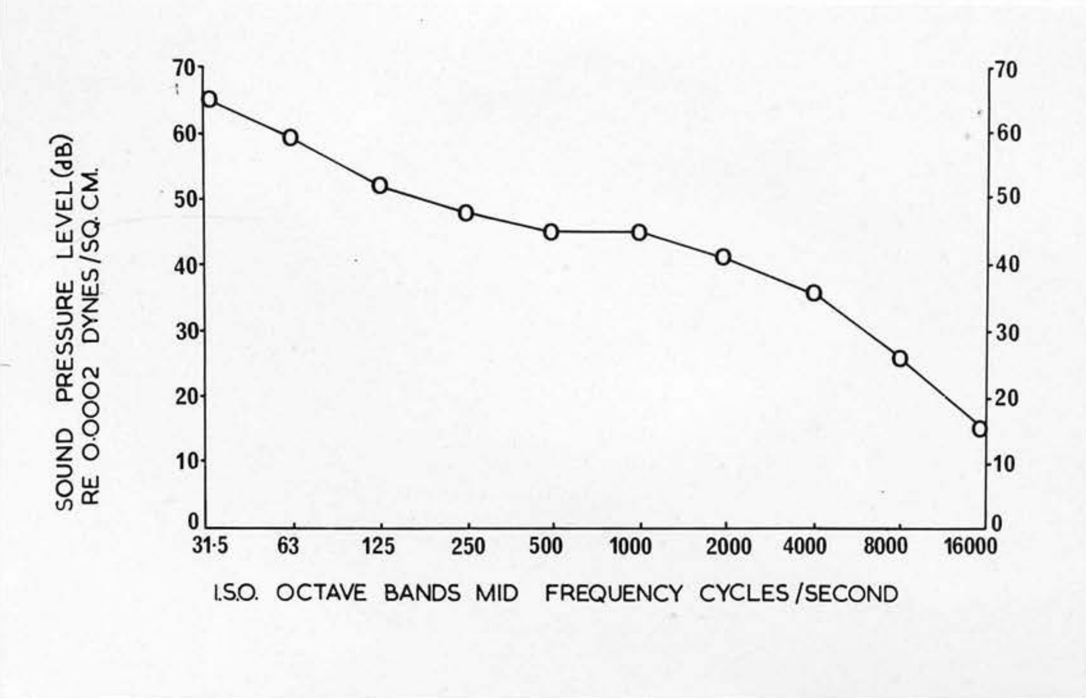

Fig. 12 Ambient Noise Spectrum in Vicinity of Jute Factory

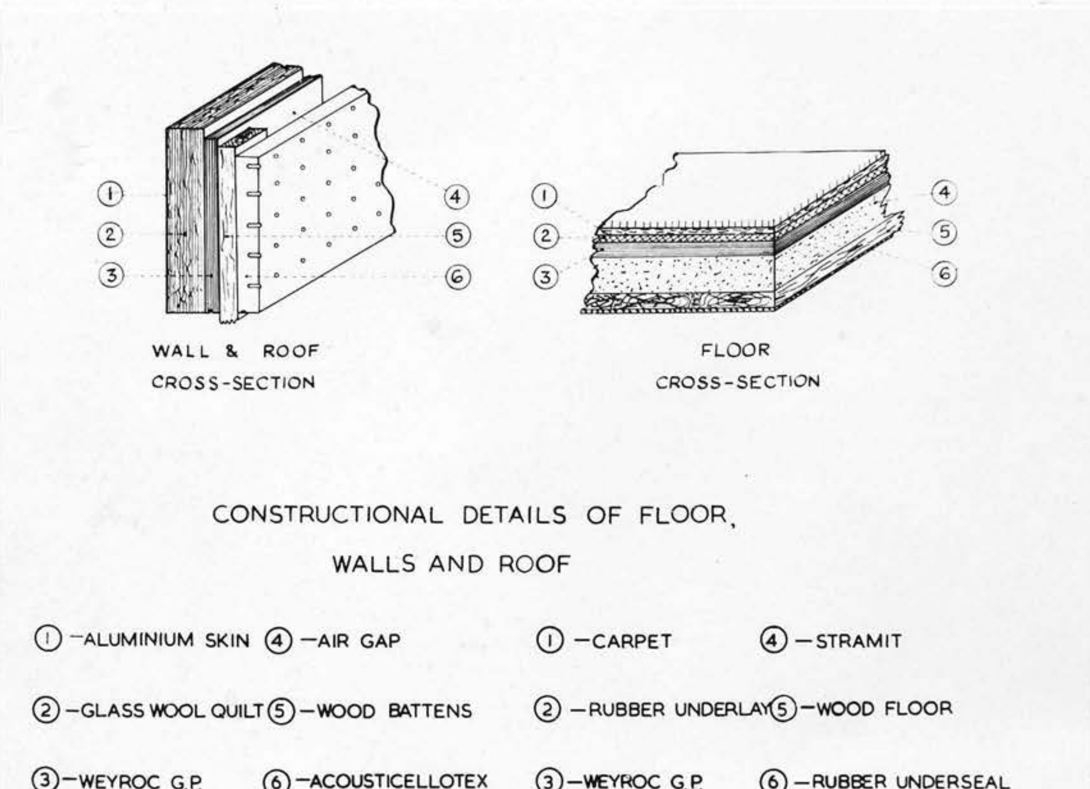

Fig. 13 Constructional Details of Floor, Walls and Ceiling

250 and 500 cps and these are often the most intense components of the ambient noise in the vicinity of jute mills. At the same time, the problem of insulating noise is greatest at the low end of the frequency spectrum. Without elaborate insulation procedures an ability to measure accurately to -10 dB is essential. The mean of the standard deviations of the hearing levels of young people with normal ears at 125, 250, 500 and 1000 cps recorded by Dadson and King [11] is 6.6 dB. Thus, in a Gaussian distribution, to which hearing levels may be considered to comform, such a limit would include approximately 86.6% of persons between the ages of 18 to 25 years. It is considered that a -10 dB hearing level limit is acceptable.

To determine the maximum sound pressure levels in the interior of the audiometric enclosure compatible with measurement of auditory thresholds to -10 dB hearing levels, calculations have been made by Burns [12] (see Appendix Table 6) for each frequency, the final column in the table showing the permissible internal noise in the inside of the commercial booth within the mobile unit. The differences between the final column in Table 1 and the spectrum of Figure 12 represents the minimum total attenuation which must be provided by the audiometric vehicle. (Table 9).

The construction of the vehicle is shown in Figures 13, 14, 15, 16 and 17. Owing to the difficulty

Table 9

Acoustic Performance of Audiometric Units in Relation to Low Frequency Ambient Noise Conditions

Unit	Frequency cps	Maximum Permissible SPL per octave to measure - 10 dB hearing level (dB)	Total Attenuation of Unit (Shell plus Booth)	Maximum Permissible SPL per octave Ambient Noise (dB)
1. Dundee	125	12	37	49
	250	6	49	55
	500	8	64	72
2. N.C.B.	125	12	38	50
	250	6	57	63
	500	8	52	60
3. Glasgow	125	12	47	59
	250	6	52	58
	500	8	64	72

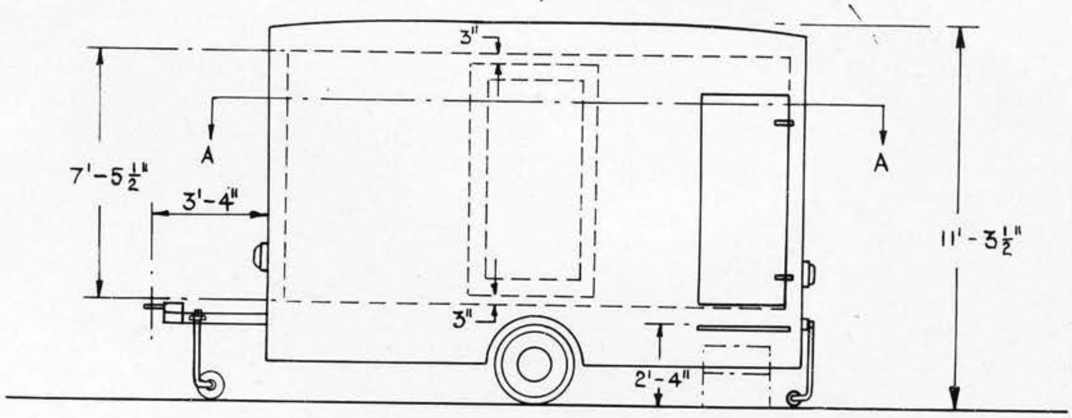

Fig. 14 Elevation of Audiometric Trailer

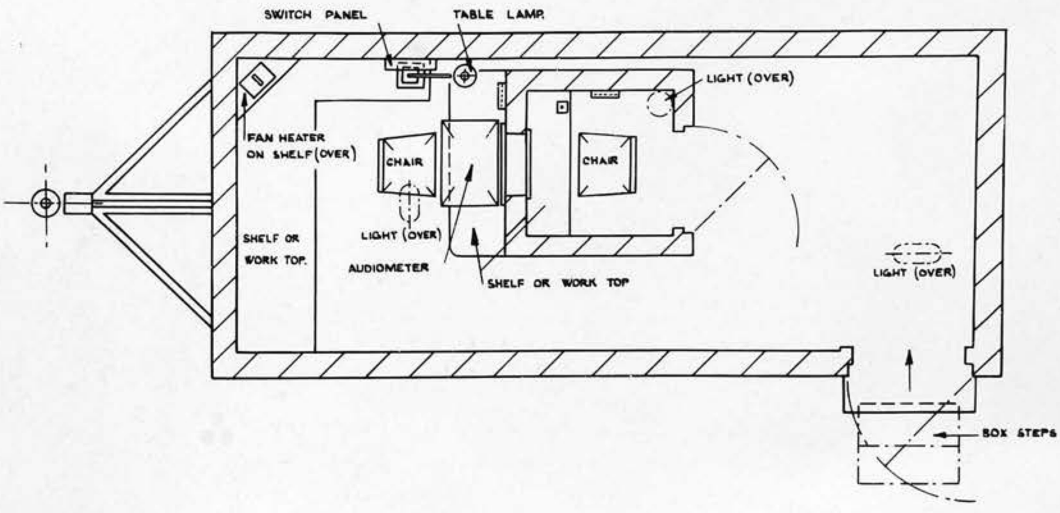

Fig. 15 Section Plan of Audiometric Trailer

Fig. 16
Audiometric Trailer

Fig. 17
Audiometry in Progress

and cost of constructing efficient forced draught ventilation, whilst at the same time retaining adequate sound insulation, no ventilation is provided in the Dundee design. Considerable attention has been given to the design of the door, the only opening in the vehicle shell. At first, a refrigerator type door lock was fitted and a Klaxon warning horn fitted externally beneath the floor, operated from within the trailer to act as an emergency warning, if, for some unforeseen reason the door could not be opened, thus trapping the operator and the patient within the vehicle. This acute emergency did actually occur (with the author trapped for a period of 5 hours) and necessitated a replacement in design of the door locks with a positive dog-catch mechanism which could be operated from within and without. In subsequent vehicle designs, a German steel door (Schmitz), the single handle of which operates a pressure lock, has been used. The quoted transmission loss for this door is 48 dB average, with a figure of 38 dB at 100 cps.

Immediately following construction the vehicle attenuation was measured by: (a) placing the trailer in the ambient noise environment of an electricity generating station in Dundee, where the overall SPL was of the order of 91.0 ± 1.0 dB with a low frequency spectrum peak around 100, 150 and 250 cps, and (b) placing the trailer in a white noise source provided by compressed air escaping from a large air reservoir in a jute mill. These results are shown in Table 7. Two other mobile units have been built to similar designs, but with chassis modifications; the second for the National Coal Board, Yorkshire and the third for the Western Regional Hospital Board, Glasgow (Dr. Fulton Christie). All these vehicles were tested in the same sound field - the Carolina Port Hydro Electric Power Station, Dundee. Data for the transmission loss as a function of frequency for the three audiometric units is shown in Table 8.

In the case of all three vehicles, the design requirements have been fulfilled at all frequencies, except at 125 cps, where the unit will measure accurately to -5 dB hearing level. This performance was considered satisfactory to proceed with hearing surveys on shcoolteachers and weavers in Dundee, the second vehicle for occupational hearing loss surveys in Yorkshire miners and the third vehicle for the determination of hearing thresholds of young school children in Glasgow.

For future research projects, the performance of mobile acoustic units could be improved by adopting the design of Thornton, 1967 (13) for the inner booth. Constructed with walls of chip and plaster board, and a density figure of 5 lb./square foot, the overall weight (675 lbs) is considerably less than that of commercial

Table 7

Details of Sound Measurements for Determination of Attenuation of Audiometric Unit

SPL (dB) Per Octave at Centre Frequency (C/S)

	31.5	63	125	250	500	1000	2000	4000	8000
Carolina Port Power Station, Dundee									
Outside shell	80	83.5	87	81	80.5	77.5	75		
Inside shell	70	69	70	54	44	37	24		
Attenuation of shell	10	14.5	17	27	36.5	40.5	51		
White noise source									
Outside shell	90	97	98	97	101	106	108	106	105
Inside shell	78	80	76	71	67	64	58	53	58
Attenuation of shell	12	17	22	26	34	42	50	53	47
Mean attenuation of vehicle shell from power station and white noise measurements where available	11	15.5	19.5	26.5	35	41	50.5		
Total attenuation outside shell to inside booth power station data	30	26.5	37	49	64.5				
White noise source data	30	30	*31	46	64	74	81	86	87
Mean total attenuation where available ..	30	28	34	47.5	64				

* This value is believed to be erroneously low, so artificially lowering the mean value.

Table 8

Transmission Loss (in dB) as a Function of Frequency for Three Mobile Audiometric Units (Dundee, N.C.B. and Glasgow)

Structure	Unit	Transmission Loss (in dB) Octave Band Centre Frequency cps							
		63	125	250	500	1000	2000	4000	8000
Unit Shell (A)	1. Dundee	14	17	27	36	40	51	54	46
	2. N.C.B.	18	12	34	40	44	54	54	46
	3. Glasgow	14	20	28	39	45	42	44	41
Booth (B)	1. Dundee - Burgess	12	20	22	28	32	33	45	51
	2. N.C.B. - I.A.C.	15	26	24	26	-	-	-	-
	3. Glasgow - I.A.C.	19	27	24	25	-	-	-	-
Total (A + B)	1. Dundee	26	37	49	64	-	-	-	-
	2. N.C.B.	33	38	57	67	-	-	-	-
	3. Glasgow	33	47	52	64	-	-	-	-

booths now available on the market, with a worthwhile reduction in wheel-bearing load. The attenuation of the Thornton booth compared with the three booths installed and tested here, and one other installed at Chapelcross Atomic Energy Authority Unit, is shown in Table 10.

Table 10

Attenuation (Transmission Loss) of Acoustic Booths

Octave Band Centre Frequency cps	Transmission Loss (dB)				
	Thornton (Southampton)	Burgess (Dundee)	I.A.C. (N.C.B.)	I.A.C. (Glasgow)	I.A.C. (Chapelcross)
125	21	20	26	27	22
250	40	22	24	24	29
500	50.5	28	26	25	33
1000	61	32	-	-	41
2000	60	33	-	-	47
4000	60	45	-	-	48
8000	64	51	-	-	39

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SECTION 3 HEARING SURVEYS

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Hearing Surveys : Group 1 Office Workers
Group 2 School Teachers
Group 3 Weavers

A. General Considerations

In Section 1, the noise environment of weavers has been defined in terms of overall intensity and spectrum analysis. In Section 2 the instrumentation to be employed in hearing surveys has been calibrated and the techniques and procedure for audiometry have been established. Limits for the test environments, as far as ambient noise levels are concerned, have been laid down. Section 3 is concerned with the technique and the result of three hearing surveys.

Measurements of hearing levels were made, in the field, according to a definite plan. First, the subject's complete noise history since leaving school was noted, in order to define any previous type and duration of noise exposure. Chadwick [1] has rightly shown the necessity for determining a complete occupational history in order to obtain a complete and reliable noise history. Second, the subject's medical history was obtained and all factors relevant to hearing, ear pathology etc. noted. Specific information was required on trauma incidents (such as concussive head injuries), Drugs (such as quinnine, salicylat and dihydrostreptomycin), tinnitus, vertigo, vomiting and allergy. Both histories were summarised in the form of a questionnaire (see Appendix A). A clinical otological examination, prior to audiometry, was then conducted, including inspection of the tympanic membrane and pharynx, with Rhinne and Weber tests to exclude a suspected conductive hearing loss. If ear wax was present in sufficient quantity to obscure the drum, it was removed and audiometry performed one week later. Subjects with current upper respiratory infection were excluded and reviewed three to four weeks later.

In the three groups surveyed (office workers, school teachers and weavers) all subjects were volunteers. In Group 1, the response of the jute office workers was difficult to assess accurately, since interruption of the constant work load tended to upset office routine, and a provisional figure of 70% was made. In Group 2, the school teacher response was between 90 to 92% and in Group 3, the weavers co-operated satisfactorily with a response of 99%.

The numbers involved in the surveys - completing the questionnaire, undergoing otological examination and pure tone air conduction audiometry were:

Table 11

Group	Description of Interests	Number Surveyed
Group 1	Office Workers	32
Group 2	School teachers	296
Group 3	Weavers	401
	TOTAL	729

Questionnaires were completed by a social worker attached to the Department of Social and Occupational Medicine, and with previous experience in epidemiological studies. In particular, the past and present noise exposure histories were checked by reference to the Factory records. All subjects listed above were then passed to the writer for clinical examination, followed by an audiometric test for both ears, lasting 12 to 15 minutes, also carried out by the writer, using the same audiometer (Peters SPD/2) in the same test environment (Mobile Acoustic Unit). The inclusion of these volunteers in the survey data presented here depended on the fulfilment of certain conditions. These were that there should be:

(1) no evidence of past or present aural disease of congenital abnormality,

(2) no history of noise (Groups 1 and 2) or to noise other than the specific weaving noise (Group 3) as already defined in Section 1, and

(3) no medical history of abnormality such as head injury or drugs.

All three considerations above would lead to middle ear or sensory-neural impairment irrelevant to our present study.

By far the most common cause of sensory-neural hearing loss and probably of all hearing loss, is advancing age [(2)] which particularly affects the higher frequencies. For the assessment of hearing, therefore, the standard for hearing thresholds which concerns young people (18 to 24 year age group) must be supplemented by additional information on the expected hearing thresholds for different ages. These values must be viewed, like any other biological standard, against the individual variability between otologically normal people. In general, presbycusis studies show the same general tendency of increasing threshold of hearing with advancing age and with increasing frequency. However, large differences (up to 10 to 12 dB) are found in absolute levels and in rates of change. Some of these differences may be explained on the basis of selection of subjects or on environmental test conditions, thus making absolute presbycusis data difficult to define. Moreover, wide variations in thresholds in each age group may be found in each published study, for example, from -5 to +75 dB at the higher 6000 to 8000 cps frequencies. Such wide variations make prediction of hearing threshold based on age very uncertain. Furthermore, the usual chronological age is found not to correspond to the physical characteristics of individuals, suggesting a biological age prediction for hearing thresholds. Renewed interest in this whole subject followed the presbycusis study of a relatively noise-free population in the Sudan by Rosen and Bergman (3) in 1962 on a secluded tribal population (the Mabaans) in the Sudan, not exposed to the tensions, noise, artificial diet and pace of western civilisation. The authors commented on the low thresholds of the Mabaans (at 80 years of age as good as an average American of 20 years) and the striking absence of raised systolic and diastolic blood pressures with increasing age. However, a more recent (1966) critical review by Bergman (4) draws attention to a possible error in the Mabaan presbycusis data and they may not have such reduced hearing thresholds as originally thought, compared with a recent set of data for young adults from an I.S.O. Study (1964). (5)

Hearing levels may also be associated with medical syndromes. Rosen and Olin (6) have suggested a relationship between coronary heart disease and hearing threshold, thus postulating a disturbance in the blood supply to the cochlea by vascular wall pathology, reduction in blood volume and destruction of the structural integrity of the specialised cells of Corti.

It may be concluded, therefore, that no complete agreement as yet exists on presbycusis values. We may interpret from the literature that male and female ears [7, 8] have equal sensitivity but in older age groups, men's hearing is inferior to women's and that the differences increase progressively with increasing age. There is good evidence [9, 3] to favour the view that greater noise exposure in men, rather than inherently more sensitive ears in women underlies these findings.

In attempting to allow for the effects of age in assessing hearing loss due to noise exposure, the usual method universally adopted has been to assume a simple additive relationship. Missouri Senate Bill, No. 167[10] concerning industrial hearing loss and recognising loss of hearing due to industrial noise as an occupational disease, specifies the method of evaluating the hearing loss for purposes of compensation. To allow for the average amount of hearing loss due to non-occupational causes found in the population at any given age (which includes presbycusis), 0.5 dB shall be deducted for each year over 40 from the average hearing level. The justification for the procedure of subtracting presbycusis values has not yet been established. It assumes that ageing and noise-induced hearing loss are similar pathological processes.

To assess the hearing loss due to loom noise in female jute weavers, two methods of approach have been adopted:

(1) For values of hearing level at various ages, the British Standard [11] has been employed for persons up to 25 years of age: for ages above 25 years, Hinchcliffe's data [12] for female ears from a random sample of a rural population in Lockerbie, Scotland. It is now assumed that deterioration of hearing due to age and due to noise are separate entities [13, 14] and that if we subtract the presbycusis value expected on the basis of age from the recorded hearing level, a value is obtained which indicates the degree of noise-induced hearing loss. A further assumption is made that the rural population from the village of Lockerbie, South Scotland would have the same hearing loss with age as the citizens of Dundee, both populations being assumed to be free from industrial noise. The difference in decibels between measured hearing level and the appropriate presbycusis value will now be known as "estimated noise-induced threshold shift".

(2) The second approach does not depend on presbycusis data obtained from other sources. A control population was sought, not subjected to industrial noise but relatively noise-free, in the sense that exposure to Dundee City noise, as opposed to a

purely rural existence, would be considered normal and characteristic of life in Dundee in the 1960's. A female population of Dundee school teachers was chosen. The noise-induced occupational hearing loss would then be calculated by the difference between weaver-teacher pairs.

It remains now to consider whether in surveys of noise exposed populations, the noise-induced threshold shift as measured is permanent (Permanent Threshold Shift - PTS) or whether the elevated auditory threshold returns to a lower value after a noise-free interval measured in hours, days, weeks, or months. In the hearing survey data presented here, an interval of not less than 56 hours, and in most cases, 72 hours, has been allowed to elapse between the last noise stimulus and the audiometric testing. The data for the weaving population has been obtained on Monday mornings (6 a.m. to 8 a.m.) prior to the commencement of work, and audiometric testing throughout the period 1962 to 1966 has therefore been confined solely to early Monday mornings. The noise-induced threshold shifts are not claimed to be "Permanent" in the sense that there is undoubtedly a small temporary component (Temporary Threshold Shift - TTS) always present.[15] On the other hand, the weavers' hearing is never better than prior to commencing the Monday morning shift and therefore, the noise-induced hearing levels as measured here are the lowest during the working year, with the possible exception of the day following the summer vacation (two weeks' duration). The legal concept of measuring true PTS after a noise-free interval of six months (as required by Statute law in the State of Missouri) is a theoretical consideration which does not apply to occupational deafness in a working, textile industry when the weekend is the only noise-free period in the weavers' life, with the exception of the annual holiday period. In the case of retired weavers, however, with noise-free intervals greater than six months, it is unlikely that a TTS component remains in the PTS measurement of hearing, although there is some evidence in this work to suggest that noise-free intervals longer than six months will be required to remove TTS completely. In this study, no TTS measurements have been made, contrary to the large bulk of American and British published studies, and no hearing measurements in noise-exposed populations have been made other than following a weekend free from loom noise and before exposure to noise begins.

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B. Hearing Levels of a Group of Relatively Noise-free Young Female Jute Office Employees

A random sample, consisting of a group of 32 young female office employees in the jute industry, were examined according to the method and technique laid down in Section 2 (C and D) and Section 3 (A). Three of this group were excluded on the grounds of ear pathology, leaving 29 subjects (58 ears) for study. These subjects were aged 18 to 25 years, to conform to the age range specified in the British Standard for normal hearing (Table 12 and Figure 18).

The hearing levels of this group are of the same order as those specified in the British Audiometric Zero (2497) defining the normal threshold of hearing for pure tones, by earphone listening. This pilot study served to demonstrate that:

(a) the basic calibration of audiometers was within the British Standard, and

(b) that British Standard Audiometric Zero could be realised within the audiometric vehicle.

Table 12

Hearing Levels of a Group of Female Jute Employees
(18 - 25 years)

Frequency (cps)	Hearing Level (dB)	Standard Error (S.E.)
125	+ 4.4	0.5
250	0.0	0.4
500	+ 1.0	0.4
1000	- 1.6	0.5
2000	+ 1.1	0.5
3000	+ 0.1	0.5
4000	- 0.7	0.6
6000	+ 2.8	0.8
8000	+ 2.7	1.0

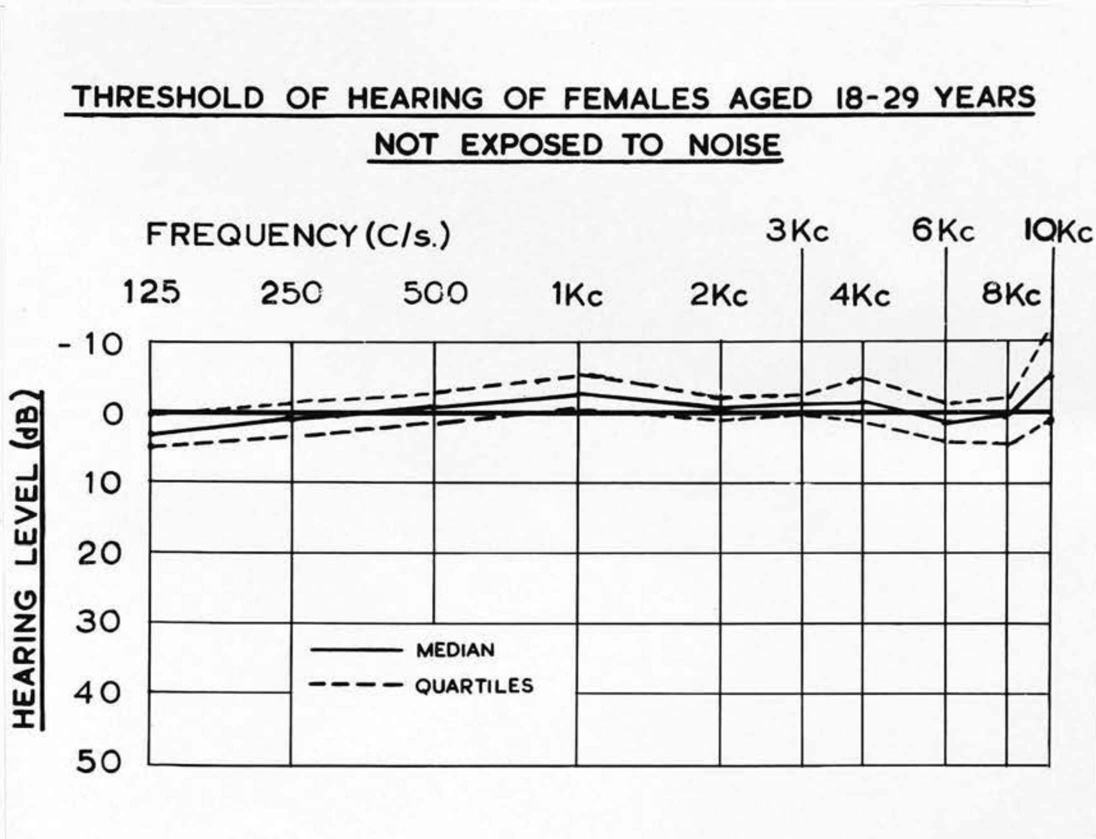

Fig. 18 : Median and Quartile Hearing Levels of Female Jute Office Workers not exposed to noise.

C. Hearing Levels of a Non-noise Exposed Population : The Dundee School Teachers

The teachers examined in this study were employed by the Local Authority and with the permission of the Dundee Education Committee, headmasters of 15 randomly chosen schools in the City were contacted. With the exception of one small school (18 teachers) which refused to join the study, a response of 95% and above was obtained in the remaining 14 schools.

In all, 296 teachers (209 female, 87 male) were examined according to the method and technique laid down in Section 2 (C and D) and Section 3 (A). For the purpose of this study, which was to provide a base line for normal hearing at various ages, the entire group of teachers required to be subjected to a low level of noise and therefore, at the time of the hearing survey, class-room noise levels were measured using the B and K sound level meter with the "A" weighted loudness scale in operation. The average dBA values found are shown in Table 13. To produce a homogeneous group, it was necessary to exclude from the analysis of the audiograms 13 teachers of technical subjects, 8 physical training instructors and 6 music teachers, these being associated with the higher noise levels (Table 14).

Numbers were still further reduced when the selection criteria for normal hearing were applied. In all, 27% (18) of the men and 16% (32) of the women were rejected for reasons shown in Table 15. The numbers

Table 13

Average Sound Pressure Levels

Classroom	Range of Values Observed (dBA)
Technical (Workshops etc.)	87 - 95
Music	80 - 87
Sports (Gymnasium)	75 - 85
English, Classics, Languages, Mathematics, Science, etc.	55 - 75

Table 14

Total Teacher Population Examined

Teacher Group	Male	Female	Total
Special Groups:			
Technical	13	-	13
P.T.	4	4	8
Music	4	2	6
With Possible Occupational Noise Exposure	21	6	27
With NO Occupational Noise Exposure	66	203	269

Table 15

Population Selected for Study

Decision	Male		Female		Total	
	No.	%	No.	%	No.	%
Not accepted for study due to:						
Ear pathology	7	10.6	19	9.4	26	9.7
Wax	2	3.0	4	2.0	6	2.2
Upper respiratory tract infection	-	-	6	3.0	6	2.2
Pre-test history of ear disease	1	1.5	-	-	1	0.4
Extraneous noise	8	12.1	1	0.5	9	3.3
Less than 18 years of age	-	-	1	0.5	1	0.4
Insufficient information	-	-	1	0.5	1	0.4
Total not accepted	18	27.3	32	15.8	50	18.6
Accepted for study	48	72.7	171	84.2	219	81.4
Total	66	100.0	203	100.0	269	100.0

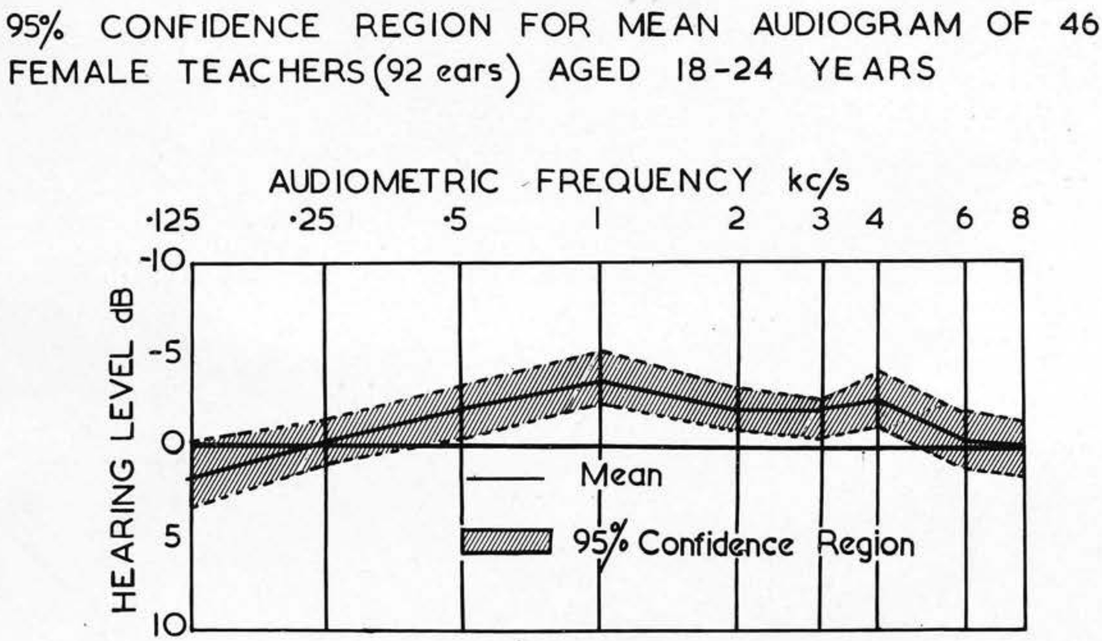

Fig. 19 : MEAN HEARING LEVELS OF 46 FEMALE TEACHERS (18 - 24 yrs.)

rejected included 6.7% (18) because of abnormalities in the ear; the second ear of these persons was not used in the survey.

The remaining 219 teachers (171 female, 48 male) were now grouped into six age groups as shown in Table 16. For the purpose of the jute weaver survey, analyses of the female audiograms only were necessary at this stage, in order to provide a control group, all of whom were women.

The necessary mathematical analyses were performed on the remaining 171 female school teachers. To increase the accuracy, the observed mean age of each group was calculated (not the mid-point of the age group) and was used for plotting the presbycusis curves. The first analysis concerned the 18 to 24 age group, in order that a comparison could be made with the jute office workers (Section 3 (B). The mean hearing level was calculated (Table 17 and Figure 19, to demonstrate the audiometric zero of this age group. It is at once evident that the mean hearing level of young teachers does not conform to the British Standard at several frequencies, including the 1 K.Hertz, being better by 3.7 dB. This one value could, however, be a chance variation and to investigate this possibility, the 95% confidence region shown in Figure 19 was constructed. The major part of the British Standard zero lies outwith this region. Calibration errors might account

Table 16

Age Analysis of Population Accepted for Study

Age Group (yrs.)	Male		Female		Total
	No.	Mean Age	No.	Mean Age	
18 - 24	7	23.3	46	22.3	53
25 - 34	12	29.5	33	28.4	45
35 - 44	10	39.3	29	39.3	39
45 - 54	12	49.4	35	50.3	47
55 - 64	6	60.3	26	58.0	32
65 - 74	1	67.0	2	65.0	3
Total	48	-	171	-	219

Table 17

Mean Threshold at 95% Confidence Limits for the Mean
For 46 Female Teachers (92 ears)
Aged 18-24 years

Level (dB)	Audiometric Frequency (kc/s)								
	0.125	0.25	0.5	1	2	3	4	6	8
Lower limit (dB)	-0.14	-2.15	-3.42	-5.04	-3.11	-2.31	-4.24	-2.08	-1.59
Mean level (dB)	1.63	-0.54	-1.96	-3.70	-2.04	-2.17	-2.65	-0.46	0.00
Upper limit (dB)	3.40	1.07	-0.50	-2.36	-1.03	-0.77	-1.06	1.16	1.59

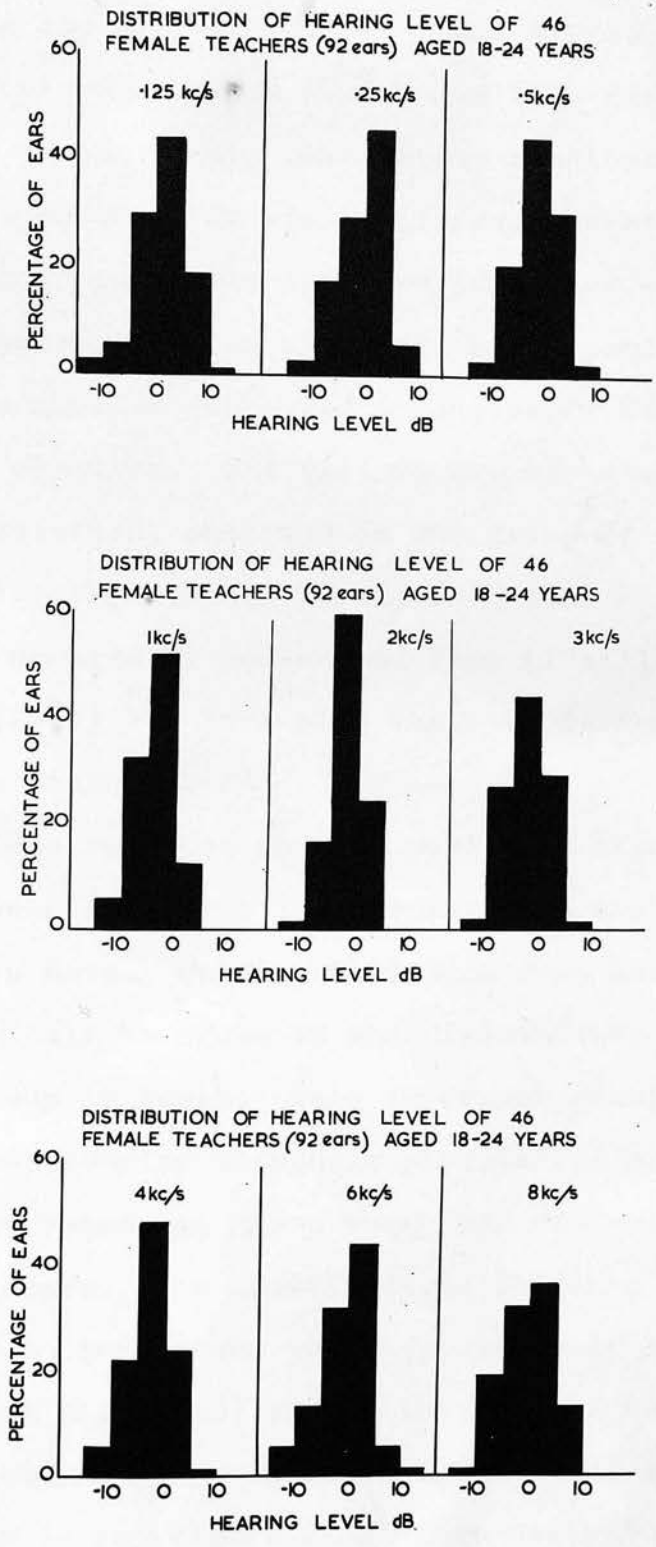

Fig. 20 : DISTRIBUTION OF HEARING LEVEL
OF FEMALE TEACHERS

for this discrepancy, but (a) the instrumentation, calibration and test environment were the same as in the survey of jute office staff, and (b) there were no consistent trends in the audiometric readings in routine audiometric checks. It was concluded, therefore, that the hearing of the women teachers in Dundee was better at some frequencies than the British Standard and this finding was further supported by the small Standard Deviations observed. The variations, measured by the standard deviation, observed in the group of teachers was significantly less ($p < 0.01$) than that reported for laboratory workers by Dadson and King (1952),[1] Rice and Coles (1967) [2] have also observed differences in the British Standard.

A serious omission in many published studies of hearing levels involving large numbers is the absence of distribution data. Valid conclusions from hearing surveys may only be drawn if the distribution of hearing within a group is known. This important statistical aspect of the hearing threshold project was examined in the 18 to 24 years age group which has departed from the British Standard. The distributions obtained for all frequencies in this group were approximately symmetrical (Table 18 and Figure 20) and in the case of 4000 cps could be reasonably approximated by a normal distribution curve (Table 19 and Figure 21). When distributions are found not significantly different from a normal

Table 18

Distribution of Hearing Level
of 46 Female Teachers (92 ears)
Aged 18 - 24 years

dB	Audiometric Frequency (kc/s)								
	0.125	0.25	0.5	1	2	3	4	6	8
- 10	2	2	2	5	1	1	5	5	1
- 5	5	16	19	29	15	24	20	12	17
0	27	27	41	47	54	40	44	29	29
5	40	42	28	11	22	26	22	40	33
10	17	5	2	0	0	1	1	5	12
15	1	0	0	0	0	0	0	1	0
Total	92	92	92	92	92	92	92	92	92

Table 19

Distribution of Hearing Level at 4 KC/S of 46 Female Teachers (92 ears) Aged 18 - 24 years

dB	Ear		
	Right	Left	Both
- 10	2	3	5
- 5	12	8	20
0	20	24	44
5	12	10	22
10	0	1	1
TOTAL	46	46	92

distribution, the average of the sample is found as a "mean" and not, as in some hearing studies, the "median". In the presbycusis study, which follows the analysis of the 18 to 24 age group, all analyses have been in terms of "the mean". The distribution of hearing level in each age group has been examined and it has been found that:

(a) the variability of the level (measured by standard deviation) increases with increasing age,

(b) in the older age groups a tendency to skewness is observed, and

(c) no significant difference exists between the mean hearing levels of right and left ears.

The older age groups have been examined in detail by Taylor et al (1967).[3]

As well as providing a control group for our weavers, the teacher survey was undertaken to measure the threshold shifts due to age in a population exposed to city noise, but with no industrial noise exposure. Ideally, serial audiometry should be studied for each patient throughout life. True threshold shift cannot be measured. The "estimated threshold shift" assumes that the mean audiogram of the 18 to 24 years age group (mean age 21.5 years) represents the hearing of the older age groups in their earlier years.[29] The audiometric data is given in the Appendix and in Figure 22, and shows the resulting estimates in the form of

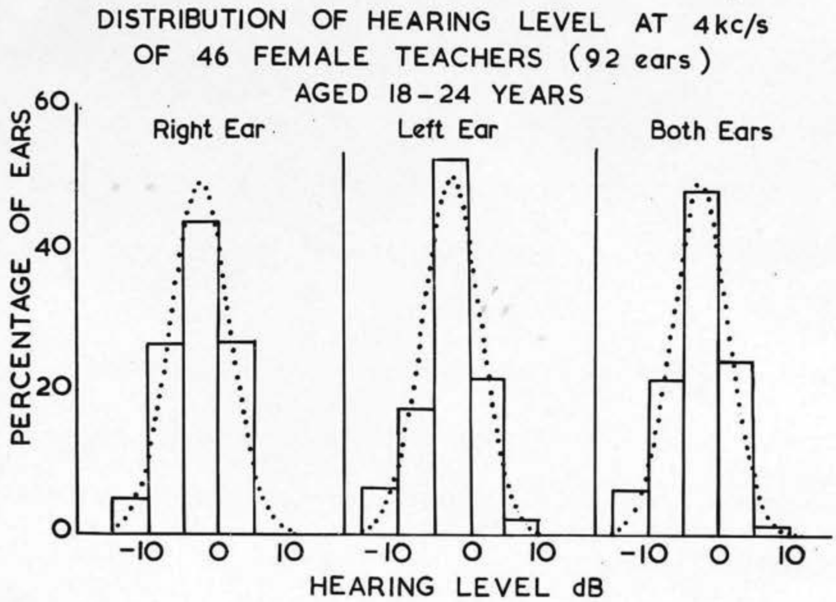

Fig. 21 : HEARING LEVEL DISTRIBUTION AT 4000 cps

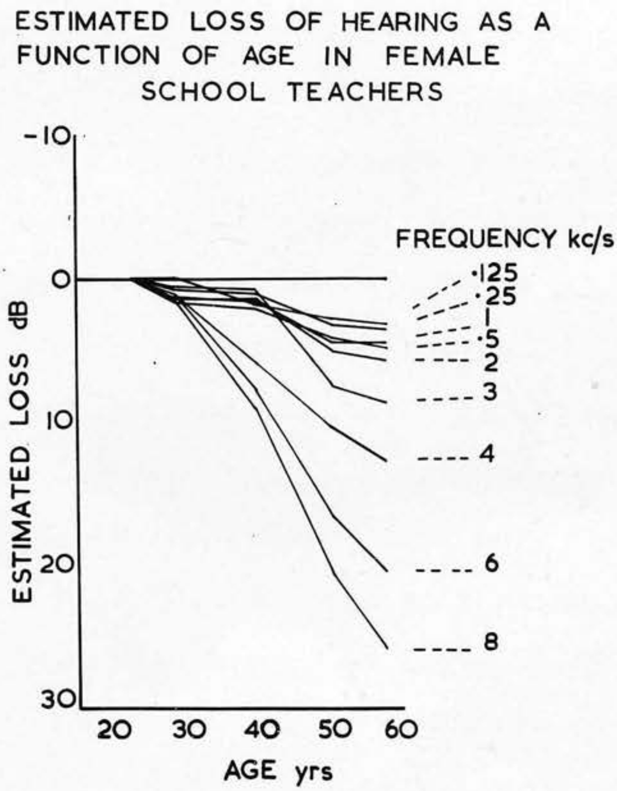

Fig. 22 : ESTIMATED HEARING LOSS WITH AGE

presbycusis curves. It will be seen that:

(a) the estimated threshold loss increases with age,

(b) the estimated threshold loss increases with frequency.

At 4000 cps the observed mean loss is 13 dB at 60 years. The estimated loss in the speech frequencies is not severe, the mean loss for the frequencies 500, 1000 and 2000 cps being 5.2 dB at 60 years, and if a fourth frequency is included (i.e. 500, 1000, 2000 and 3000 cps) is 6.3 dB.

In order to test the validity of our measurements, a comparison was made at two frequencies (4000 and 8000 cps) between the Dundee school teacher population and two other populations, namely that of Hinchcliffe (1959) and that of Corso (1963) (Table 20 and Figure 23). At 4000 and 8000 cps no major differences were observed between the estimates of presbycusis obtained in this work and the studies of Hinchcliffe and Corso, within the 95% confidence region.

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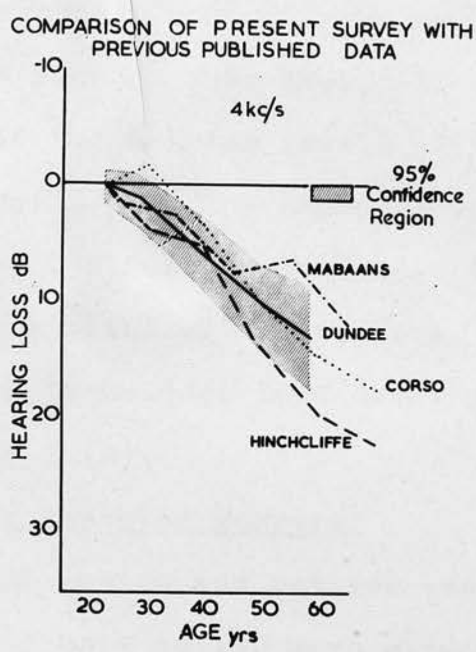
Table 20

95% Confidence Limits for Mean Estimated Presbycusis Loss at 4 kc/s and 8 kc/s for different ages

dB	4 kc/s			8 kc/s		
	Lower Limit	Mean	Upper Limit	Lower Limit	Mean	Upper Limit
18 - 24	-1.40	0	1.40	-1.44	0	1.44
25 - 34	-1.12	1.17	3.46	-0.82	1.51	3.84
35 - 44	2.39	5.84	9.29	5.65	9.14	12.63
45 - 54	6.77	10.44	14.11	13.80	20.37	26.94
55 - 64	8.02	12.80	17.58	19.28	25.77	32.26



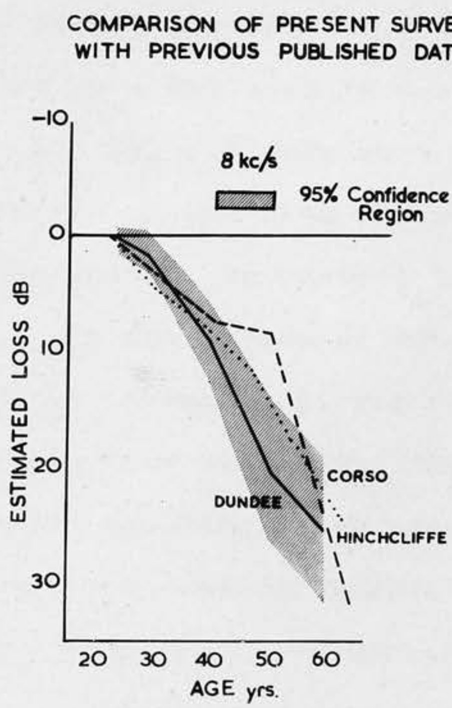


Fig. 23 : PRESBYCUSIS DATA IN PRESENT SURVEY COMPARED WITH PUBLISHED DATA

D. Hearing Levels of Female Jute Weavers in Dundee

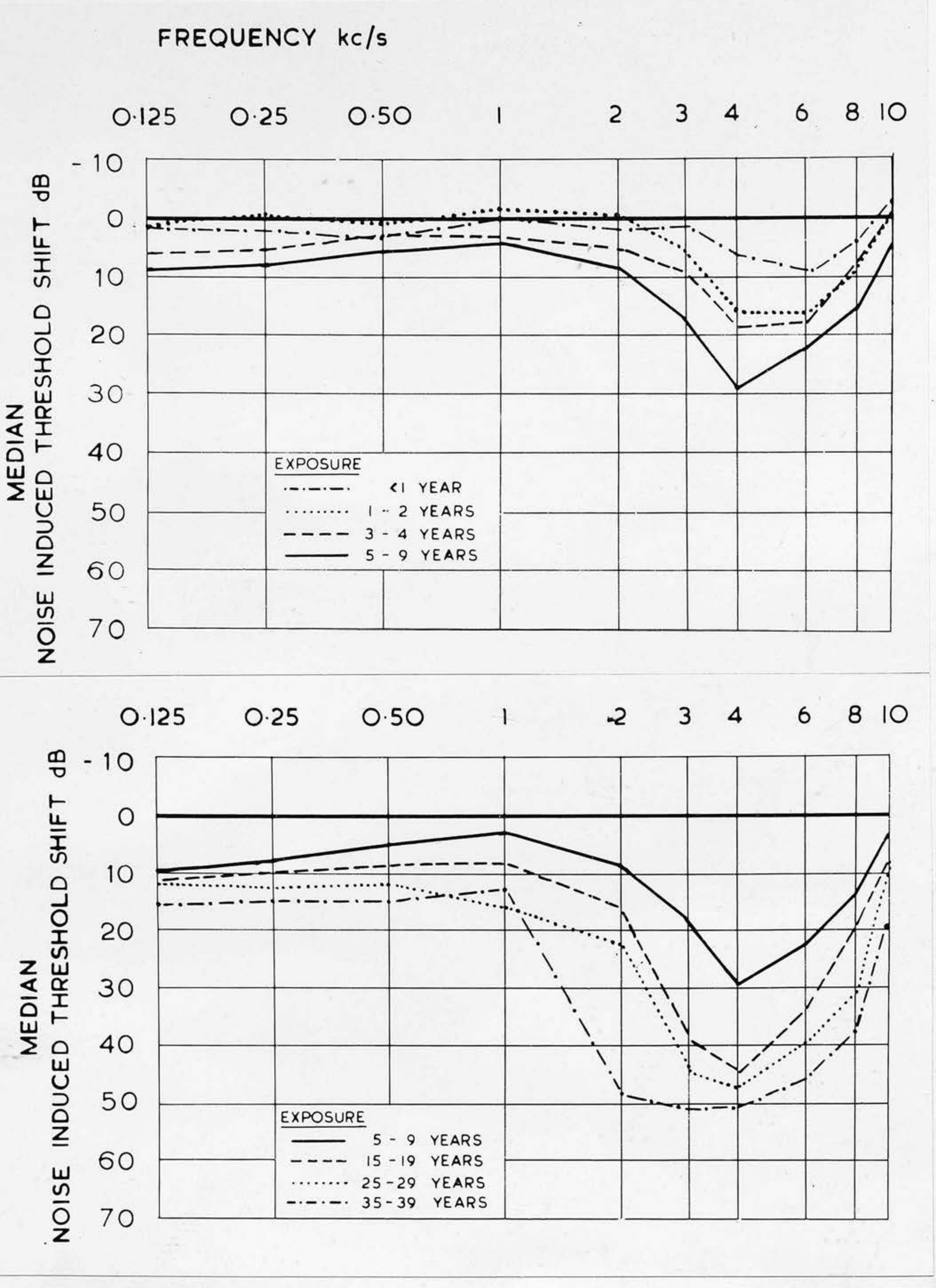
The main part of this thesis is concerned with the measurement of the hearing levels of two groups of female weavers: Group 1 - Employed weavers in active service; Group 2 - Retired weavers. Both groups, consisting of a total of 401 weavers, were examined by the method and techniques laid down in Section 2 (C and D) and Section 3 (A).

Group 1 : Employed Weavers

Of the 401 active and retired weavers examined, the audiometric data on 150 were eliminated because of failure to satisfy the selection criteria. Thus, 251 weavers remained. In 9 of these, one ear was discarded on account of pathology, leaving a total of 493 ears. Of these, there were 461 ears in Group 1, leaving 32 ears in Group 2. All subjects were volunteers, in that they were asked to attend both the works surgeries and the audiometric booth. In Group 1 the response was 98% and in Group 2, in the region of 90%.

In the first instance, it was decided, in view of the unusual employment stability, the absence of extraneous noise, the long noise exposure periods (up to 50 years) and the unchanging spectrum and overall noise levels over the last 70 years, to study Groups 1 and 2 outwith previously measured Dundee controls by using the British Standard for persons up to 25 years of age, and for ages above 25 years, Hinchcliffe's data

Fig. 24 Development of Noise-induced Threshold Shift (Early and Late)



for female ears, taken from a random sample of a rural population in Lockerbie, Scotland. Thus the base line in this first treatment of the weavers is the hearing levels of young female office employees in the jute industry, otologically normal and aged 18 to 25 years. The presbycusis data for ages above 25 years taken from Hinchcliffe, will be subtracted from the recorded hearing level at any particular frequency to obtain the "estimated noise-induced threshold shift".

In contrast to the teachers, wide individual variation was found in recorded hearing levels, particularly in the older age groups. Therefore, in this first treatment, "medians" were used in place of "means", even although the mathematical analysis is rendered more difficult and less flexible. With the observed wide variations in recorded hearing levels, it was desirable to express the results as the 25th percentile, median and 75th percentile.

The results for Group 1 (461 ears) are given thus:

(1) Median and Quartile estimated noise-induced threshold shift as a function of frequency for different durations of loom noise exposure. Appendix, table 30, and graphically in Figure 24.

(2) Estimated noise-induced threshold shift (median) as a function of years of exposure (parameter-frequency). (Figure 25).

(3) A knowledge of the distribution of the noise-

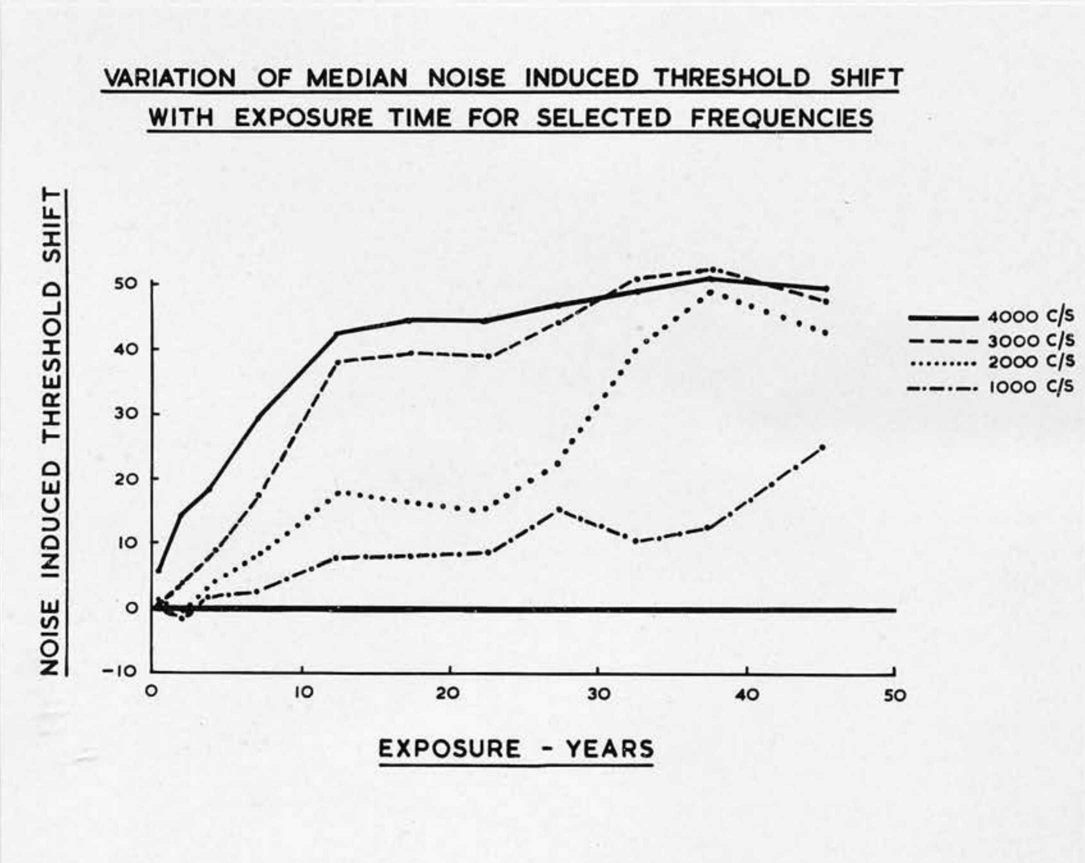


Fig. 25 : Estimated Noise-Induced Threshold Shift at 1000, 2000, 3000 and 4000 c/s as a function of duration of exposure (in years)

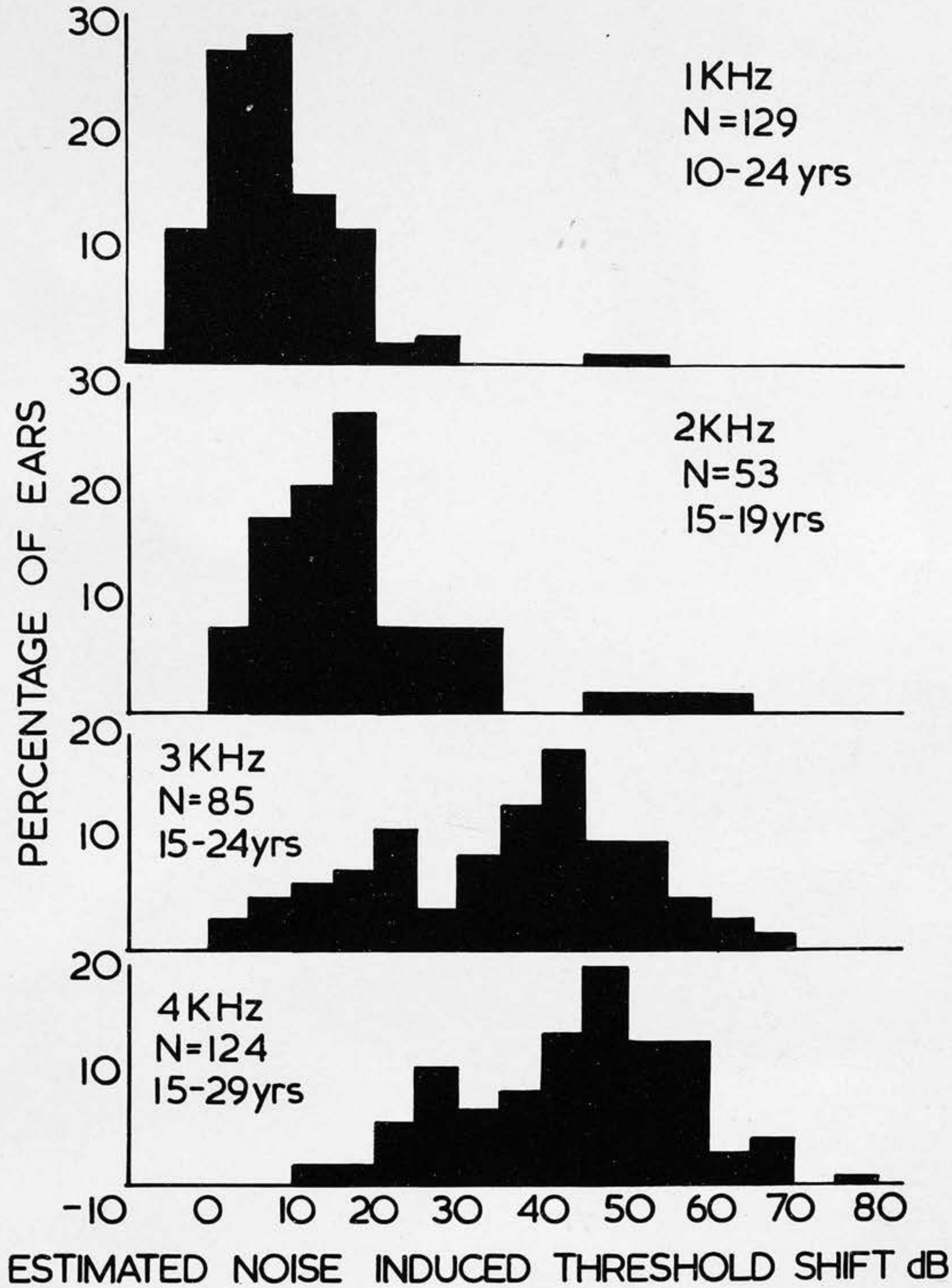


Fig. 26 : Distribution of estimated noise-induced threshold shift at 1000, 2000, 3000 and 4000 cps at various duration of exposure. Audiometer steps 5 dB. N = ears.

induced threshold shifts in the weaver population is necessary for comparison with the teacher control group. The present data have been examined for distribution of noise-induced threshold shift in ranges of exposure throughout which little change or progressive noise-induced deterioration has occurred (Figure 26), for example, 1000 cps from the 10 to 24 year age range. The histograms show asymetry (compare teachers) and some isolated values, especially at 2000 cps. There is, however, no gross departure from normality, although it is evident from Figure 26 that deviation tends to increase with increase in audiometric frequency.

Group 2 - Retired weavers

The group of retired weavers consists of 32 ears with a mean duration of loom noise exposure of 46 years, mean age 69 years and a mean duration of retirement of 6.3 years, that is, freedom from loom noise. For presbycusis data in this treatment, Hinchcliffe's rural population in the 65 to 74 years age bracket in terms of median hearing levels has been used as an age-matched control population. The numbers are small, since the survey inclusion criteria exclude 70 to 75% of experimental subjects in this high age group. The results, which give some indication of the consequences of a lifetime of occupational exposure to loom noise are shown in Figure 27 and Appendix, table 31.

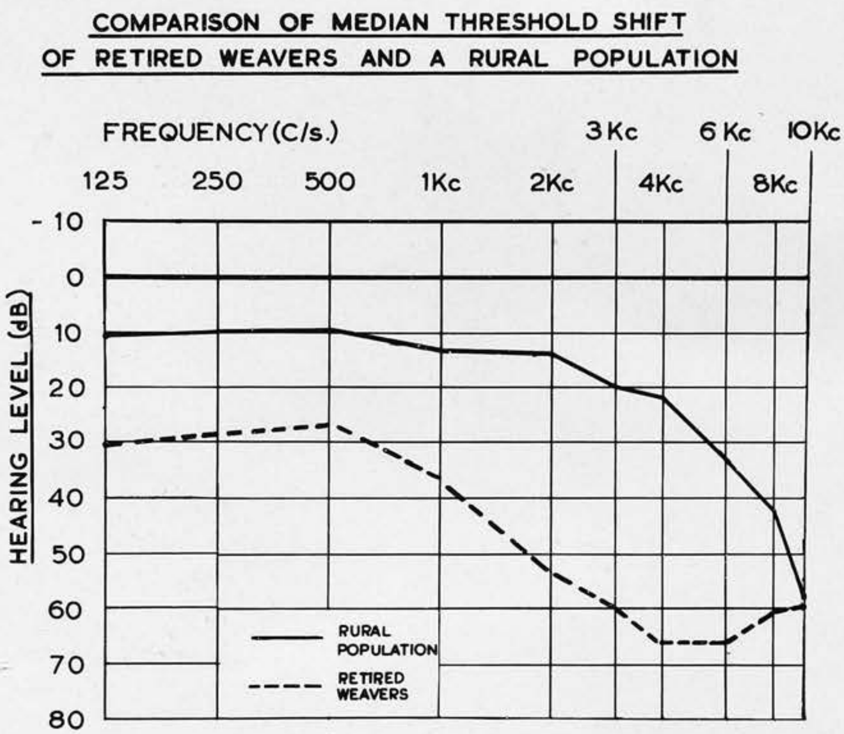


Fig. 27 : Median Estimated Noise-Induced Threshold Shift as a Function of Frequency for Retired Weavers compared with an age-matched rural population (Hinchcliffe's data)

E. Evaluation of Occupational Hearing Loss in Female Jute Weavers

In Section 3 (D) the audiometric data obtained from 461 ears of weavers were analysed and the estimated noise-induced threshold shift obtained for various age groups as a function of years of loom noise exposure, using the presbycusis data of Hinchcliffe (Treatment 1). A second possible statistical method (Treatment II) and the main objective of this work, was to compare the hearing levels of the weaver population with the hearing levels of a control group exposed to urban noise (as opposed to rural), namely the Dundee school teachers. The ultimate aim was thus to compare the hearing levels of two age and sex matched populations using the same audiometric apparatus, in the same test environment, the instrumentation being held to the same basic calibration. It must be pointed out, however, that although in one of these populations - the school teachers - there is no problem concerning PTS-TTS differences, in the other - the weaver population - there is no implication of the degree of "permanence" of the noise-induced hearing loss, since some temporary component, although small, is almost certainly present. Thus, the hearing levels of the weavers, measured on Monday mornings, will be raised by an estimated 3 to 5 dB compared with the same audiometric data taken, say six months after the cessation of weaving activities, which would be the recommended procedure if hearing measure-

Table 21

The Number of Weaver-Teacher Pairs and the Mean Age Difference between Weaver-Teacher Pairs.

Noise Exposure (yrs)	Number of weaver-teacher pairs	Mean Age Difference between weaver-teacher pairs (yrs)
Less than 1	15	- 4.9
1 - 2	10	- 3.9
3 - 4	12	- 3.2
5 - 9	20	+ 0.05
10 - 14	20	- 0.05
15 - 19	17	+ 0.64
20 - 24	14	- 0.35
25 - 29	11	- 1.1
30 - 34	17	+ 0.11
35+	19	- 0.10

ments were required for compensation and legal purposes. Apart from this small PTS-TTS variable, the maximum number of variables have been controlled in Treatment II in order that an accurate statistical comparison may be made between the two populations.

The method of comparing the noise exposed weaver population and the non-noise exposed school teacher controls was to match weaver-teacher pairs. From the two populations, pairs were selected with equal loom noise exposure (within one completed year) and of equal age. For this type of comparison, very large populations were required to control the two variables of noise exposure and age difference. Therefore, even with the large weaving population available in Dundee, it has been possible to get a satisfactory number of pairs only in certain noise exposure groups, namely, 15 pairs - less than 1 year, 20 pairs - 5 to 9 years, 20 pairs - 10 to 14 years, 17 pairs - 15 to 19 years, 17 pairs - 30 to 34 years and 19 pairs in 35+ years. In the ten noise exposure groups, <u>mean age</u> differences between the weaver-teacher pairs have been held to very close limits within the range -5 to +0.64 years (Table 21). By means of the I.B.M. computer 1620, the audiometric data for each of the noise exposure groups were processed. In each of the ten groups of pairs, the mean difference (in dB) in hearing level at each of eight audiometric frequencies was obtained for Right (R) and

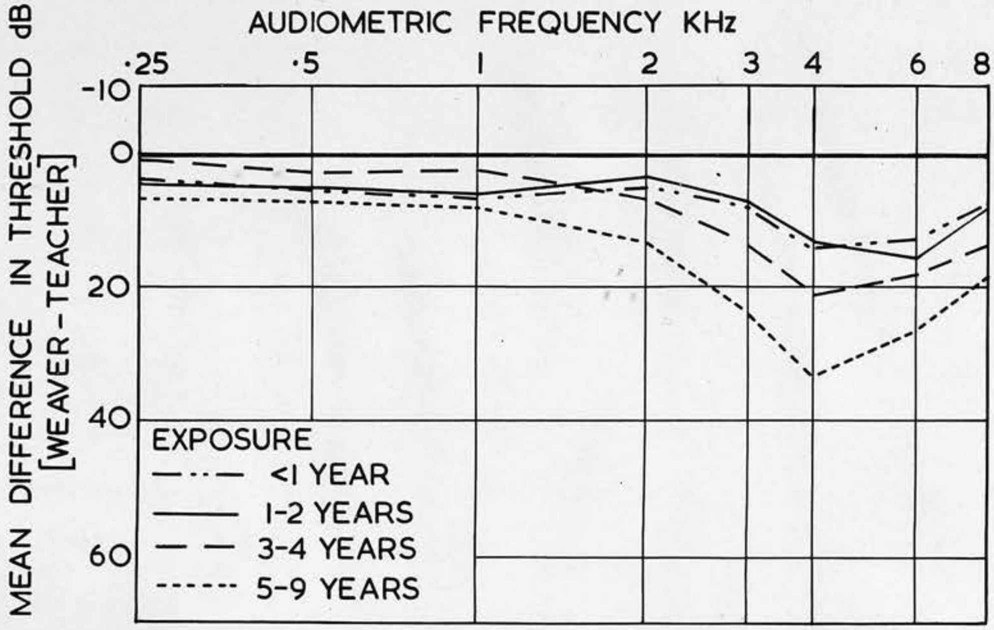


Fig. 28 : MEAN DIFFERENCE IN THRESHOLD (WEAVER-TEACHER) PAIRS AS A FUNCTION OF FREQUENCY (EARLY)

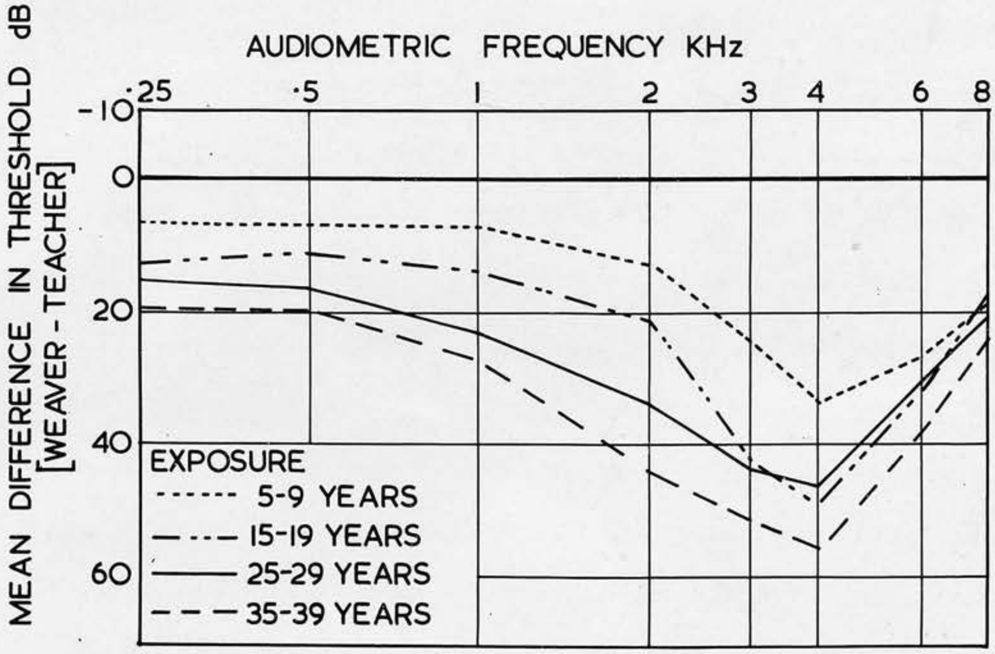


Fig. 28A : MEAN DIFFERENCE IN THRESHOLD (WEAVER-TEACHER) PAIRS AS A FUNCTION OF FREQUENCY (LATE)

Left (L) ears, the difference R - L, and the average. The computer data processing was also asked to give values for variance, including the Standard Error for the ten groups at each of the eight frequencies and for R and L ears. The results for all groups are presented in ten Tables (Appendix 32) which all depict mean differences in hearing level between weaver-teacher pairs as a function of frequency, parameter-duration of loom noise exposure. From this data, it is now possible to construct a further Table (22) showing the mean differences in Threshold (weaver-teacher pairs) as a function of years of noise exposure, parameter-frequency (Figures 28 and 29).

Table 22

Mean Estimated Noise-Induced Threshold Shift
as a Function of Frequency for Various Durations of Exposure

Noise Exposure (completed years)	Frequency (K.Hertz)							
	0.25	0.50	1	2	3	4	6	8
Less than 1	3.2	5.7	6.4	4.9	7.9	13.6	12.1	6.7
1 - 2	3.7	5.2	6.1	3.0	7.0	13.1	14.9	7.9
3 - 4	0.8	2.8	2.4	6.3	13.0	21.1	17.9	13.6
5 - 9	6.8	6.9	7.4	12.6	24.1	33.5	26.6	18.5
10 - 14	11.4	9.8	10.4	15.5	34.3	42.1	27.5	14.7
15 - 19	12.7	11.0	13.5	21.4	42.6	49.0	32.0	17.6
20 - 24	11.2	9.8	10.8	21.5	40.0	46.4	34.5	18.2
25 - 29	15.3	16.4	23.0	33.9	43.7	46.2	35.0	20.1
30 - 34	8.7	9.9	15.7	36.5	46.2	50.5	33.9	15.5
35+	19.6	19.7	27.4	44.3	51.6	55.7	38.4	23.6

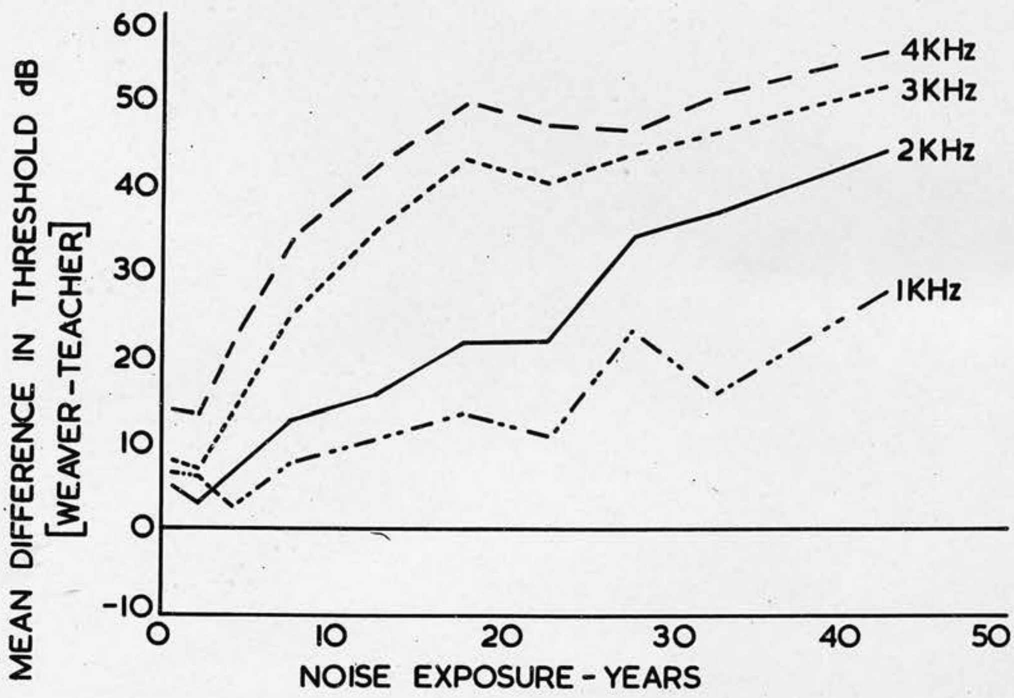


Fig. 29 : MEAN DIFFERENCE IN THRESHOLD (WEAVER-TEACHER) PAIRS AS A FUNCTION OF DURATION OF EXPOSURE FOR 1000, 2000, 3000 and 4000 cps.

SOCIAL DISABILITY OF WEAVERS

THE SOCIAL DISABILITY OF WEAVERS

Throughout the experimental work on the jute weaver population, the clinical otological examinations and the conversations during the history taking, an attempt was constantly being made to assess the degree of social disability or handicap present in the weaver in speech communication in quiet surroundings. Early in the study it was felt that a discrepancy existed, in that the hearing impairment as judged from the pure tone audiogram, did not match the social disability experienced by the weaver in her normal, leisure environment. It was decided, therefore, before proceeding to a final evaluation of jute weaving as a hearing hazard based on pure tone audiometry, to carry out a small subjective pilot study to correlate hearing loss with social impairment. It could be argued, for example, that pure tone audiometry is not, in itself, a measure of social disability and that it is fundamentally wrong to base legislation or compensation for hearing loss on an average audiogram loss without some evidence that the injury has resulted in a loss of man's enjoyment, or a decrease in his social activities.

A questionnaire was designed to assess the social disability of weavers inside the factory, in the home and engaged in social pursuits. The questions (see Appendix B) ranged widely from the subject's own

Table 23

Age Distribution of Group Interviewed
57 Weavers plus 4 Non-weaver controls

Age (years)	No. in Group
under 45	2
45 - 49	13
50 - 54	10
55 - 59	25
60 - 64	11
TOTAL	61

assessment of her hearing and the reaction of family and friends, to the development of compensatory skills over a life time of weaving. In all, seventy-nine questions were asked at interview.

The number of weavers with the age distribution of the group interviewed is shown in Table 23. In all, 57 selected at random, were interviewed by the writer; the mean age was 54 years. There were 20 weavers in the 45 to 54 year range, 24 in the 55 to 59 year range and 11 in the 60 to 64 year range. The mean loom noise exposure of these weavers was 34 years, 16 weavers having had 40 to 49 years constant loom noise - a remarkable employment stability (Table 24).

It was desirable to have some idea of the pure tone hearing loss, although this could have been assessed from the audiometric data now available (Section 3). The median and quartile hearing levels of 39 of the 57 female weavers interviewed is shown in Figure 30. The graphs follow the usual pattern seen in Section 3. By definition, 25% of this population were better than Q1, 25% were between Q1 and Q2, 25% between Q2 and Q3 and 25% were worse than Q3. The results are in agreement with the 30+ years of noise exposure in Section 3.

Processing of the 61 questionnaires (each with 79 questions) and including 4 controls, revealed that there were six factors which gave consistent replies and indicated areas of disability and adaption. These were:

Table 24

Time in Loom Noise
(Weavers Only)

Noise Exposure (years)	No. in Group
10 - 19	6
20 - 29	10
30 - 39	25
40 - 49	16
TOTAL	57

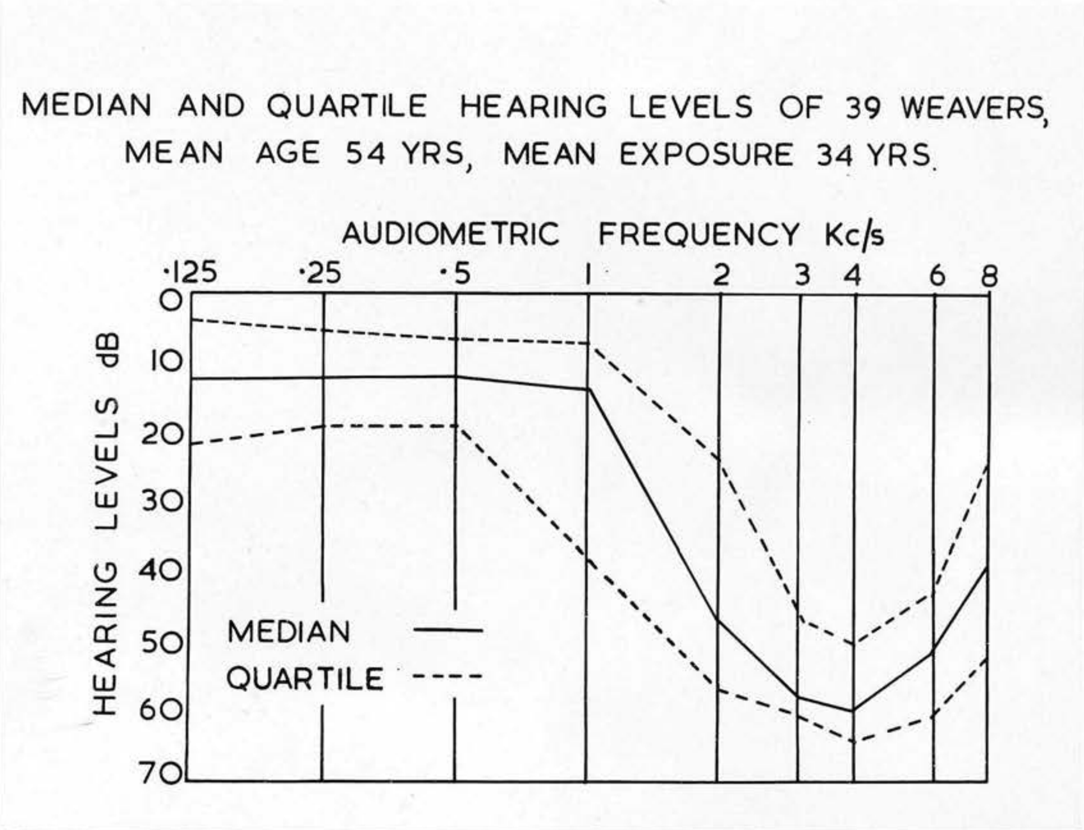


Fig. 30 : Median and Quartile Hearing Levels of
39 Weavers, Mean Age 54 yrs.,
Mean Noise Exposure 34 yrs.

(1) Lip Reading - Thirty five weavers (61%) practised some form of lip reading, and 11 of these professed to be expert (15%), using this acquired skill both at home and in the factory.

(2) Sign Language - Thirty six weavers (63%) used this method of communication, but only at work.

(3) Conversation in noisy surroundings - Forty nine weavers (86%) expressed the view that communication was difficult in a noisy background, whether produced by machinery or other voices ("cocktail party" effect), whether at work or at home. Train, traffic and bus background noise made communication difficult. In many (thirty nine weavers - 68%) inability to hear against a background of noise was the first indication of impairment.

(4) Telephone - Forty three weavers (75%) had a dislike of and an inability to use the telephone. Speech discrimination proved the major difficulty. There was no opportunity when on the telephone to cover up for speech not understood, as deaf subjects are prone to do in face-to-face conversation.

(5) Public Meetings - Impairment in twenty eight weavers (49%) was indicated by adjustment of positions in hall or church, front seats being a necessity. A further nine weavers (16%) found it

impossible to attend church, cinemas and public meetings - a withdrawal action.

(6) Dislike of Loud Noises - During the early stages of impairment, loudness recruitment was evident in twenty six weavers (46%) but as hearing deteriorated, shouting and high volume on wireless or television were tolerated.

Contrary to expectations, reactions of other members of the household, friends and neighbours did not give a measure of hearing deterioration. There were two main reasons for unsatisfactory replies:

(a) Many of the weavers were spinsters and lived alone,

(b) In some households, teenagers listened to music played at very high noise levels which could not be tolerated by weavers despite the large loss seen in their audiograms. In general, listening levels of children and teenagers in this present age appear to be rising (even whilst they study) and this factor is a source of annoyance to weavers, especially if recruitment is present.

The behaviour of the weavers in Dundee city traffic was investigated. Sight appeared to be more important than hearing (especially at pedestrian crossings with "Cross Now" lights). As hearing deteriorates, weavers are unable to wear head-squares, especially if these are fabricated of noise-insulating material, such as heavy plastic.

Five (9%) of the 57 weavers had hearing aids but only in one case was the aid worn constantly at home. Twelve (21%) weavers expressed a desire to try out amplification, in view of the difficulty experienced in speech, in particular with a second or more voices present at the same time. All twelve weavers expressed concern at the high price to be paid for hearing aids, in particular for "behind the ear" types. All expressed a dislike of the present National Health Service hearing aid, the main complaint being its conspicuous bulk and the presence of the lead from the amplifier to the earpiece.

The meetings held with the 57 weavers, with a mean loom noise exposure of 34 years, left the interviewer (W.T.) with the following impressions (not, as yet, statistically controlled).

(a) This generation of hard working, loyal and happy people does not appear to be concerned about or, to a certain extent, to be aware of their disability.

(b) Hearing loss is accepted as a part of weaving.

(c) In 50% of the sample, the mother had also been a weaver and thus, tradition played a part in associating deafness with weaving, and accepting this impairment as part of the occupation.

(d) In this sample, no gross psychiatric disturbances related to noise could be found, as judged by the interviewer.

(e) A gradual adaptation process is going on, particularly with regard to speech intelligibility and discrimination. Thus, the speech disability is <u>not</u> as marked as one would expect from examination of the pure tone audiogram.

(f) Fifty (87%) of the sample did not consciously hear loom noise at work; that is, they were not aware of the noise, except on Monday mornings (initial two to three hours), following a weekend, or for three to four days following a fortnight's holiday. At other times, they were only aware of the changing frequency of the shuttle impact as the cop within the shuttle ran down in size. With the exception of the two periods above, loom weaving noise was not regarded as annoying, irritating or even unpleasant.

DISCUSSION

DISCUSSION

Because of the stable nature of the weaver population in Dundee, and exposure of this population to a steady state noise of around 100 dB ± 2 dB with constant spectra showing maxima in the octaves 1000 and 2000 cps, it has been possible to study the progress of hearing deterioration for periods up to 50 years of exposure (Section 3D). Using Hinchcliffe's presbycusis data, inspection of Figure 24 shows that at durations of exposure up to two years, the median estimated noise-induced threshold shift is not more than about 5 dB up to and including 3000 cps. The first and most severely affected frequency is 4000 cps with 6000 cps as nearly affected in the early stages. This pattern is the usual one seen when the human ear is exposed to broad band noise, with no marked peaks. With further loom noise exposure (Figure 24) the notch or 4 kc dip increases in depth, becomes wider and ultimately, at exposure years above 35, cuts off the upper range of the speech frequencies.

Examination of the estimated noise-induced threshold shift as a function of duration of exposure (parameter frequency) for 4000, 3000 and 2000 cps (Figure 25) indicates that initially the rate of deterioration of hearing is high and proceeds to grow rapidly until after an interval of twelve to fifteen years, stabilisation occurs and deterioration attributable to noise is at a low rate for the next thirty years. The 3000 cps curve follows a similar pattern, but the 2000 cps curve flattens out around fifteen years, but shows another secondary deterioration between twenty and twenty-five years. This secondary deterioration at 2000 cps is so great (over 30 dB in fifteen years) it is unlikely to be fortuitous. A similar result has been obtained by Nixon and Glorig in 1961.[1] After an exposure duration above thirty-five years, further deterioration due to noise virtually ceases in the frequencies 2000, 3000 and 4000 cps, but still persists at 1000 cps. In making these observations, it is necessary to be aware of the distribution of noise-induced threshold dips. There is a wide variation in the interquartile range of values at different frequencies and durations of exposure, ranging from less than 5 dB at the lower frequencies and shorter exposure durations, to 30 dB at longer durations. These large interquartile intervals are particularly associated with the 2000 cps frequency at the intermediate durations of exposure (twenty to thirty-five years). The interquartile range tends to diminish in the region of 4000 cps at the longest duration of exposure. In this forty to forty-two year noise exposure group, the striking feature is that hearing loss at 4000 cps showed a mean of 50.2 dB with a 25% quartile of 41.5 dB and a 75% quartile of 55.3 dB (Note that presbycusis has been subtracted from all the above measured thresholds using Hinchcliffe's data).

A similar method of treatment of the data may be followed using the weaver-teacher pair results. The progress of deterioration of the weavers, using the paired teacher as a control, may be seen to follow a similar pattern (Figure 28), 4000 and 6000 cps being the first and most severely affected in the early stages. Again this difference in threshold between the weaver-teacher population is greatest at the early years of loom noise exposure for the 3000 and 4000 cps frequencies but around fifteen years exposure, stabilisation or a saturation process occurs and further impairment of hearing proceeds at a low rate for the next twenty or thirty years. In the weaver-teacher pair treatment, however, particularly in the noise exposure years less than one, and from one to two, the difference between the weavers and teachers thresholds (judged by the weaver-teacher pair processed data) is very large compared with the same noise exposure values using Hinchcliffe's data. The rate of deterioration in the very early years is thus seen to be approximately twice as great. The curves for 1000, 2000, 3000 and 4000 cps in the early exposure years all show a flattening similar to that seen in the 2000 cps curve by Hinchcliffe's method and which is again seen around the twenty to twenty-five year noise exposure. The reason for these high early losses or deterioration is readily seen if we compare the Dundee teacher data with Hinchcliffe's rural Lockerbie population. In the Dundee 18 to 24 year age group of school teachers, the mean hearing level (dB) of this group differed significantly from the British Standard for normal hearing (500 cps: -2.93, 1000 cps: -4.02, 2000 cps: -2.17 and 3000 cps: -2.34). Thus, although at 4000 cps and 8000 cps no major differences were discovered between the estimates of presbycusis in the Dundee teachers and that of Hinchcliffe and Corso in the age groups 25 - 34, 35 - 44, 45 - 54 and 55 - 64, yet the striking feature of the Dundee Teacher Study is the better than British Standard hearing level in the 18 to 24 age group. Hinchcliffe, by comparison, referred all his later presbycusis data to his 18 to 24 age group, which then became his British Standard zero. As far as evaluation of impairment of weavers is concerned, the initial hearing losses in the period up to three to four years may well be much higher than originally assessed using Hinchcliffe's data. When the mean threshold difference (weaver-teacher) is plotted as a function of years of exposure, (Figure 29) then, apart from the greater deterioration in the early years, the shapes of the curves for all frequencies are in general agreement with those already obtained by Treatment I.

Assessment of Hearing Impairment

In 1959, the Sub-Committee on Noise, and approved by the American Academy of Ophthalmology and Otolaryngology, presented as a guide for hearing impairment, a method for both measurement and calculation.(2) "Impairment" as used here denotes a medical condition which affects one's personal efficiency in the activities of normal living. "Disability", on the other hand, is recognised as involving non-medical factors, such as a reduction in ability to remain employed at full wages. Impairment should be evaluated in terms of ability to hear everyday speech, but because of the present limitations of speech audiometry, the hearing level for speech must be estimated from measurements made by pure tone audiometry. For this estimate, the Sub-Committee recommended the simple average of the pure tone hearing levels at the three frequencies, 500, 1000 and 2000 cps. In 1959, no specific recommendations regarding a correction for a shift in hearing threshold due to age was made in America, "because the relation of presbycusis to noise-induced hearing loss is not yet fully understood".(3)

The "Low Fence" or beginning of impairment, of Davis, obtained by the "three average" method (500, 1000 and 2000 cps) is located between 15 and 18 dB, American Standard. Since all hearing surveys in this work are to British Standard, then for all practical

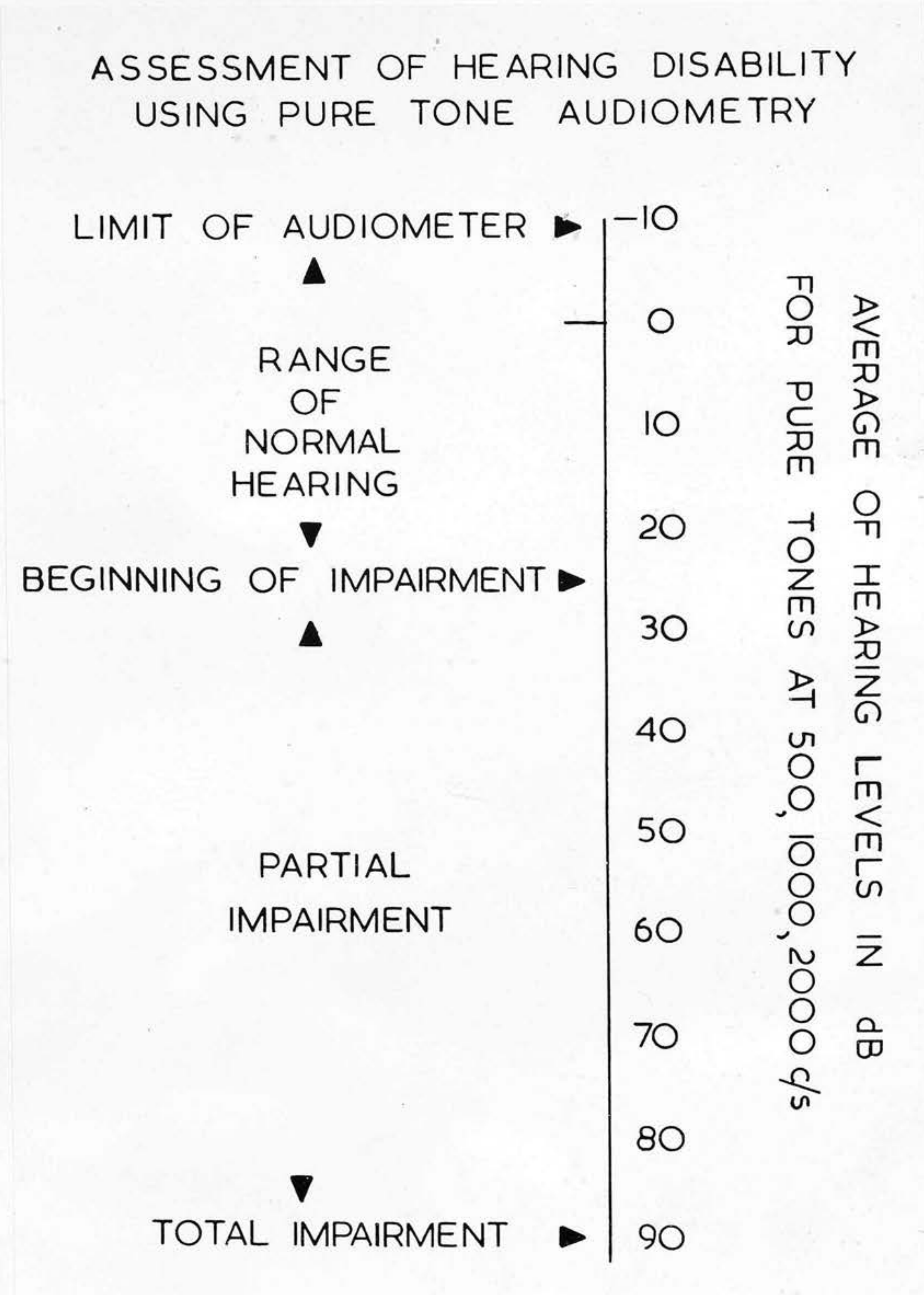


Fig. 31 Assessment of Hearing Disability
Using Pure Tone Audiometry

purposes, the beginning of impairment may be taken as 25 dB (Figure 31).

There is at present (1967) no international standard or base line for speech audiometry. Legislation in other countries relies, therefore, solely on pure tone audiometry. There is, in this context, another view [4] that because all speech frequencies are involved, then the 3000 cps frequency should somehow also be included. The simplest method is to average the "four" frequencies - the "four average" method. The "Low Fence" on British Standard using the four frequencies (500, 1000, 2000 and 3000 cps) is 30 dB.

If the lower limit, namely 25 dB (3 average) and 30 dB (4 average) is taken as the reference level for the ability to hear everyday speech under everyday conditions, then at the other extreme, if the averages are 90 dB (3 average) and 95 dB (4 average) the impairment for everyday speech should be considered total.

Applying the above impairment scales to the data obtained from the four groups of weavers and the teacher controls, the results obtained are shown in Table 25.

It will be observed from the table that the "three average" impairment for the teacher control group is 3.8 dB whereas that for the active weavers is 34.3 dB, this difference being entirely occupational in origin, due to loom noise exposure of 35+ years. It is of interest to look at the measured hearing levels in the

Table 25

Evaluation of Hearing Impairment

Weavers and Controls

Population	Loom Noise Exposure (years)	Impairment "3" average *	Impairment "4" average +
Group 1 (Active Weavers Section 3D)	35 - 39	Q1 - 20.4 Q2 - 28.2 Q3 - 38.2	Q1 - 28.3 Q2 - 35.7 Q3 - 44.3
	40 - 52	Q1 - 25.2 Q2 - 35.7 Q3 - 46.6	Q1 - 32.8 Q2 - 42.1 Q3 - 51.8
Group 2 (Retired Weavers Section 3D)	46	Q2 - 38.4	Q2 - 43.8
Group 3 (Active Weavers Social Study) Section 8	34	Q1 - 8.5 Q2 - 27.2 Q3 - 38.0	Q1 - 20.6 Q2 - 31.5 Q3 - 43.7
Group 5 Teachers (Controls)	zero	mean - 3.8	mean - 4.6
Range of Impairment		Beginning: 25 Complete: 90	Beginning: 30 Complete: 95

* "3" average = 500, 1000 and 2000 cps ÷3

+ "4" average = 500, 1000, 2000 and 3000 cps ÷4 weaver-teacher study at all frequencies and compare the weavers (35+ noise exposure group) with the teachers (Table 26).

Table 26

Measured Median Hearing Levels as a Function of Frequency 35+ Years Exposure

Frequency cps	250	500	1000	2000	3000	4000	6000	8000
Teachers Control Group	3.7	3.7	2.3	5.5	6.7	9.0	21.7	28.2
Weavers paired by age and noise exposure	23.3	23.4	29.7	49.8	58.3	64.3	60.1	51.7

Loom Noise Exposure - 35+ years

"Three Average" Mean - 34.3 dB (within the Impairment Area)

This table may be taken as evidence and proof that loom noise, as measured in Dundee, of around 100 dB overall SPL causes serious damage to hearing. Measured on the American "three average" scale, after a life time of weaving and exposure to 100 dB, 50% of the weavers are in the area of partial impairment. If the active weavers in Group 1 are now examined where quartile distribution data is available, then the mean of the median Q2 on the "three average" scale is 28.3 dB for the 35 to 39 year exposure, and 35.7 dB for the 40 to 52 year exposure, which again places 50% of the weavers in the partial impairment area. Group 3, the social study weavers, also gives a Q2 of 27.2 dB with 50% of weavers within the impairment range. It may, therefore, be concluded from the data obtained in this study that 50% of weavers, as judged from pure tone audiometry and applying impairment scales in use in America, are impaired to some degree and this is usually the ability to understand everyday speech under normal conditions.

The American Academy of Ophthalmology and Otolaryngology, as well as defining the impairment area (above 25 dB B.S.) set a limit at 40 dB (British Standard) again using the "three average" (500, 1000 and 2000 cps), as representing the practical limit of hearing without amplification, i.e. the limit at which hearing aids are required. Therefore, in order to assess the degree of impairment at long duration noise exposure times, 40 to 52 years of loom noise, and to arrive at some indication of the consequences of a life time of occupational exposure to loom noise at 100 dB overall SPL, the quartile data for the largest number of active weavers with the longest exposure was examined (Table 27)

By definition, 25% of the measured hearing levels (without presbycusis correction) will be worse than the

Table 27

Measured Median Hearing Levels of Active Weavers with 40-52 years loom noise exposure

Population Active Weavers	Noise Exposure (years)	Quartile	Frequency (cps) 250	500	1000	2000	3000	4000	6000	8000
Group 1	40	Q1	15.5	15.1	19.1	41.3	55.7	61.3	55.9	45.2
N = 32	‡	Q2	23.5	23.0	31.5	52.5	61.3	65.9	63.6	56.1
	52	Q3	29.9	32.9	45.3	61.5	76.6	69.9	72.3	66.0

40-52 Exposure Years	Q1	25.2
"3" Average	Q2	35.7
(500, 1000 and 2000 cps)	Q3	46.6

Q3 quartile figure given in Table 27. If the "three average" method be now applied to the Q3 quartile for the 40 to 52 year noise exposure group, then the Q3 "three average" exceeds 40 (46.6). Therefore, 25% of our Dundee weavers, after a life time of weaving, have reached the limit of hearing where amplification is needed for successful everyday communication. The amplification required may be provided by a hearing aid or by the raised voice.

The practical limit of hearing at the 40 dB level represents a concensus of opinion from otologists and audiologists in the States. It is a nominal figure and may not apply equally well to all shapes of noise-induced audiograms. There is evidence, from the social study of Dundee weavers, that apart from the recognised difficulties with telephone, public meetings, conversation in noisy surroundings, a slow process of adaptation is proceeding in subjects exposed to one type of noise for a life time. Using the "four average" method, better correlation was obtained between pure tone audiometry and social impairment.(5) The reason for this may lie in the shape of the audiogram resulting from jute loom noise. Some of the Dundee weavers are seriously impaired, judged by pure tone audiometry, but they do not appear to be impaired socially to the same degree. The explanation of these differences will require a very large study numerically, in order to

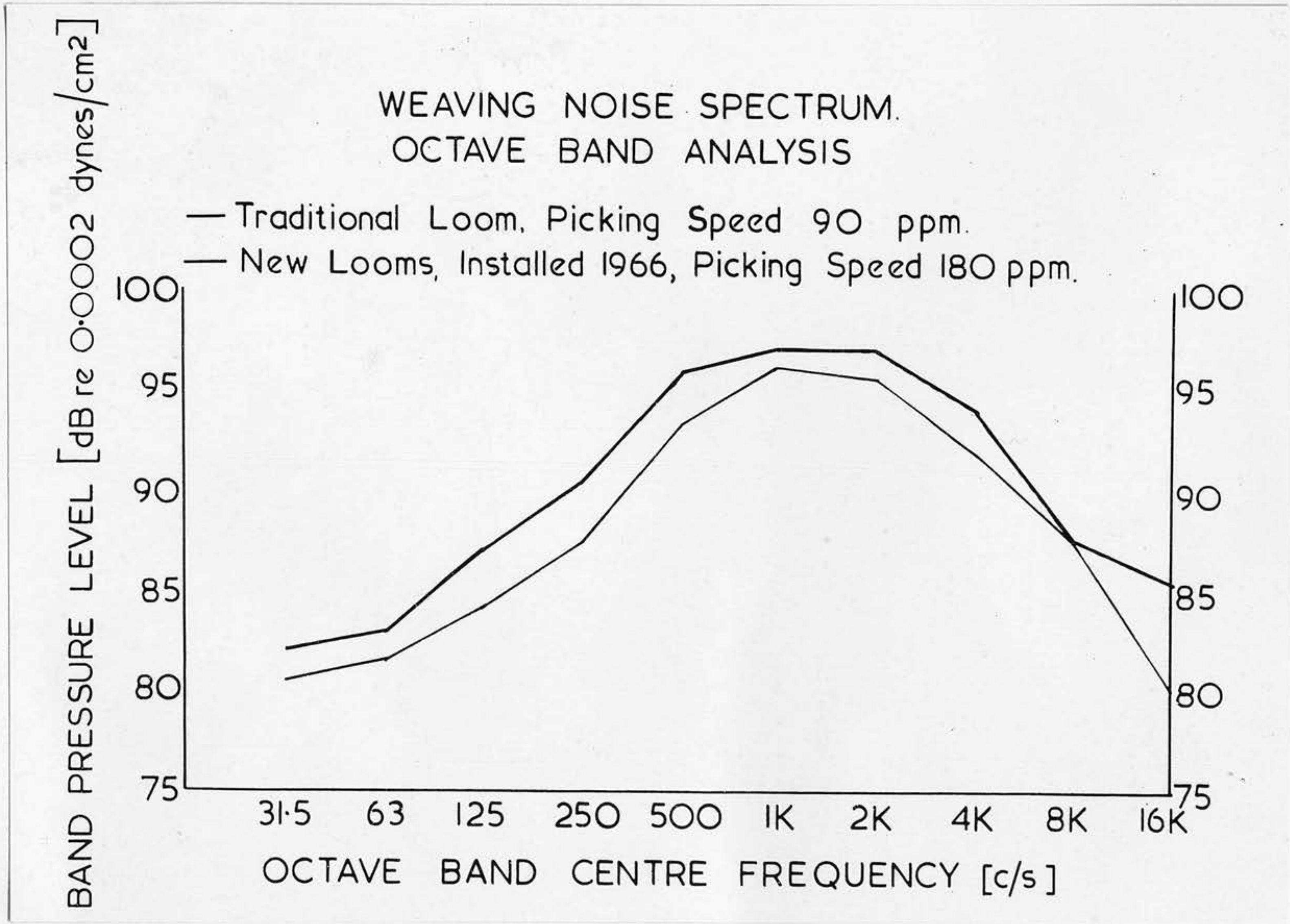


Fig. 32 Weaving Noise Spectrum. Octave Band Analysis
Comparison of traditional loom and new loom type installed 1966

towards what was considered to be unavoidable noise, now requires re-appraisal. In 1966, new "PICANOL" looms of Belgian manufacture appeared in Dundee and were installed in three factories. Owing to the demand for increased production per loom, the pick speed has been increased from 90 - 100, to 180 - 190 picks per minute. The overall SPL has doubled to 102 - 103 dB centred mainly at 500, 1000 and 2000 cps as in the old 70 to 80 year old looms (Figure 32 and Table 28). A second, new narrow loom type, manufactured in Dundee for the export market, has also been discovered (1967) with an overall SPL of 99.5 dB or 99 dB(A) rating for a single test loom, with a picking speed of 160 picks per minute. Obviously, production is the over-riding consideration, and noise as a hazard to hearing, subsidiary. It is disappointing, therefore, to report at this stage, when industry in general is becoming aware of the danger to human hearing of high intensity noise, the introduction of these new, narrow looms into some areas of jute and flax manufacture with approximately double the noise intensities of the old, narrow, overpick, flat jute looms installed over eighty years ago and now becoming obsolete. It is not in line with recent recommendations for noise control in industry as set out in the Wilson Report (1963).[6]

Table 28

Noise Data for Different Loom Types

Overall S.P.L.	Octave Band Pressure Levels (dB) Centre Frequency cps	Jute Narrow Loom (90 picks per) minute	Belgian Loom PICANOL (180 picks per) minute	Dundee Narrow Loom New Type (157 picks per) minute
dB Linear	-	99.5	103	99.5
dB(A) Scale	-	99.5	102	99
	31.5	81	82	85
	63	82	83	82
	125	84	87	80
	250	87	90	83
	500	92.5	96	91
	1000	95.5	97	92
	2000	94.5	97	92
	4000	92	94	87
	8000	87	87.5	82
	16000	80	85.5	70

Control of Occupational Hearing Loss

In the course of this study on noise-induced persistent threshold shift (NIPTS), as far back as 1830, Fosbroke assumed that there was an inherent difference in noise susceptibility among various individuals. Some of the factors thought to be involved are genetic,[7] somatotype,[8] middle ear muscle reflexes,[9] mastoid pneumatization[10] and pre-exposure threshold.[11] In the jute mills and factories, a principle of self-selection is at work. Weaving noise, as discussed here, is considered to be only of moderate intensity and is, on the whole, well tolerated. Over the course of six years' medical supervision, only three "susceptibles" have required to be transferred to quieter departments. The proportion of the labour force leaving weaving because of the noise levels is therefore small. In other departments, such as cop-winding, where the noise levels are in the region of 106 to 110 dB with a peak at 4000 cps, the labour turnover is high and there is a preponderence of ear pathology (25% of a group of 38 winders).

Loom noise does, however, discourage recruitment, particularly in the school-leaving group new entrants.

In general, a diseased ear is less susceptible to noise damage and a conductive deafness frequently behaves like an ear protector. From the hearing loss data presented in this thesis, it became obvious early

Fig. 33 Noise Protection Devices (1967)

(1) Ear Muffs

(2) Ear Plugs or Inserts

(3) Billesholms Glass Wool

in the work that personal protection of the weavers would eventually be a necessity. As far back as 1954, Dickson [12] reported on the evaluation of a number of ear protectors. A second method is that of Fletcher and Loeb [13] (1962) where the reduction in the temporary threshold shift (TTS) in protected ears is compared with that in unprotected ears. Knight and Coles [14] (1966) have shown that permanent hearing losses do not occur in aircraft carrier flight deck personnel working in intermittent noise with overall sound levels up to 150 dB SPL when fluid-sealed ear muffs are worn. No attempt has been made throughout this investigation to mount a hearing conservation programme except in one weaving shed where Billsholme "Glass Down" was recommended as an ear plug. This material, developed in Sweden, has been used with some success (over 50% volunteer protection cover) in other industries and in other countries, but in the one weaving shed where dispensers for the glass wool were installed, the percentage of the employees protected fell from 90% to 15 - 20% in six to nine months. Since, from the data presented here, we know that the rate of deterioration is most rapid in the early (10 to 15) years of noise exposure, serious attempts must be made by the combined Jute Industry in Dundee to mount a hearing conservation programme commencing with new entrants, and protecting them in the all-important early years. The attenuation figures available for glass wool as an ear plug are such that weaving noise at 100 - 110 dB overall SPL is reduced below the Damage Risk Criteria [15] or below the recommended "A" rating figure of 85 dB(A). Unfortunately, since the early hearing losses are in the region of 4000 and 6000 cps, and are outwith the speech range and are therefore undetected except by audiometry, the wearing and acceptance of ear protection in any form has been, and will always be, a problem. Success will only be attained if both pre-employment and serial auditory threshold measurements become compulsory, where operators are subjected to a high noise level environment. It is still not possible to predict noise susceptibility other than by serial audiometry which implies a measure of hearing loss, which is irreversible, before the diagnosis is made. Because of the statistical relationship between Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) [16,17] noise susceptibility tests offer some hope of defining "noise susceptibles" before a great deal of irreversible damage has occurred. Recently, however, Ward [18] (1966) has introduced further complications in showing that TTS and PTS are, to a certain extent, frequency dependent, and that the spectrum of the stimulus may alter this simple direct relationship.

Legislation : The Future

Noise-induced deafness was recognised as an occupational disease in the U.S.S.R. in 1929. A number of other states, including Bulgaria, Czechoslovakia, Denmark, France, Germany, Italy, Turkey and certain States of the U.S.A. (Wisconsin) followed.[19] In 1959, Senate Bill No. 167 (State of Missouri) included in this new law, two sections recognising loss of hearing due to industrial noise as an occupational disease and specifying the method of evaluating the hearing loss for purposes of compensation. The method of evaluating followed the principles approved by the A.M.A. in 1955 and by the American Academy of Ophthalmology and Otolaryngology. In America, therefore, as long ago as 1954-55, a bill had been drafted to compensate for hearing impairment and quickly came to the Statute Book in 1959. In Britain, noise-induced deafness is still not an accepted occupational disease.

In 1907, the Departmental Committee on Compensation for Industrial Diseases (the Samuel Committee) reported that boilermakers' deafness is unquestionably an injury due to employment. At that time, it could not be included in claims under the Workmen's Compensation Acts on the grounds of incapacity, for it does not prevent a man from continuing his trade. However, the Workmen's Compensation Act was replaced in 1946 by the National Insurance (Industrial Injuries) Act and under Section 55, a disease which causes loss of faculty (and not necessarily loss of wages) may be prescribed under this Act. In an uncomplicated noise-induced deafness, therefore, where pre-employment and serial audiometry show hearing loss due to a noisy environment at work, there would appear to be no reason why claims should not now be successful. On the other hand, as was demonstrated in the high wastage in a relatively stable population of weavers (150 eliminated from 401), uncomplicated, pure noise exposure cases without ear pathology and with an accurately known time factor are comparatively rare, especially in males. The variables are difficult to control in this field. Furthermore, the correlation between pure tone audiometry and social impairment has not yet been fully investigated. A pilot study has been made here. A second attempt will be made by combining a questionnaire technique with speech audiometry and comparing both with the pure tone audiogram. The opinion held now, and supported by this work, is that legislation based on pure tone audiometry (as in the countries and States above) would not give an accurate scale (either on the "three average" or the "four average") upon which to base a monetary compensation scheme. This does not mean that the weavers studied here are not impaired, for it has been shown that at least a fifth are in the hearing aid range after a life time of weaving. But the evidence is that the pure tone audiogram alone is not sufficient as a basis for a legal system of payment in Britain.

There is a second method of attacking the problem of noise in Industry. It is not logical to protect noise-exposed employees without first tackling the problem of reducing machinery noise at source and in particular, the question of the noise levels of new machinery. Following the Recommendations of the Wilson Report (1963) and the Annual Report of H.M. Chief Inspector of Factories on Industrial Health (1965) "The problem of noise reduction may be tackled in different ways. Undoubtedly the best way is to reduce the noise at its source, which requires consideration of design of machines, their modification and noise reduction". It is true that insufficient attention is being paid at present to new machinery noise levels and if legislation must be brought in to control noise as a whole, then maximum recommended noise level limits should first be set for industrial premises. At the present time, there is no legislation on maximum levels permitted within works. The Factory Inspectorate recommend 85 dB(A) but it is evident from the work reported here that industry considers hearing loss in employees as secondary to production demands. Annoyance, irritation or nuisance outside factory premises has indeed received more recognition, in that a British Standard has recently been issued (1967) [20] which aims at controlling community reaction to noise (B.S. 4142).

Finally, it will be evident that if Britain ultimately follows other countries and prescribes noise-induced deafness as an industrial disease, only by the evidence from pre-employment and serial audiometry can a case be judged at Law. It is unfortunate that at present there appears to be no certain, single audiometric test which would unequivocally point to a diagnosis of noise-induced deafness.

In most of our noisy industries in Britain, workers must continue to rely mainly on personal protective devices (Figure 33). The equipment must be cheap, comfortable, easy to clean and wear, if such devices are to be widely accepted. Under certain unfavourable conditions, such as heat and high humidity, existing designs are not yet satisfactory. Another field of research requiring further work is in the use of amplification devices, especially adapted for the neuro-sensory perceptive hearing loss found in weavers.

Over the last fifty years, a wealth of information on noise and hearing loss has been accumulated. In this country, however, no real progress has yet been made in the prevention of deafness. It may well be asked what progress has been made since the "Regimen Sanitatis Salernitanum" in A.D. 1150 noted that: (21)

> Blows, falls and noise ....
> All these, as is by sundry proofs appearing
> Breed tingling in the ears, and hurt on hearing.

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CONCLUSIONS

CONCLUSIONS

(1) The noise levels found in jute weaving cover a wide range of over-all values, dependent on loom size and type. The female weavers operating narrow, flat, over-pick looms 43 inches and 63 inches in width, are subjected to noise in the range 99 to 102 dB overall SPL at the work position. The noise is of a broad band continuous type with transients of peak amplitude 15 to 18 dB above the mean level corresponding to shuttle and picking-arm impacts. The rate of impact does not exceed 18 per second and therefore jute weaving noise is considered to have a true impact component.

(2) To provide a control population not exposed to industrial noise, the hearing thresholds of 296 school teachers in Dundee were measured by pure tone earphone listening. The results indicate that this population has more acute hearing than the British Standard in the 18 to 24 year age group; the variability observed was smaller than that in the population used to establish the British Standard; and the presbycusis data (18 to 65 years age group) showed close agreement with standards already accepted in Britain, namely the data of Hinchcliffe and Corso.

(3) A retrospective survey of 401 female jute weavers exposed to noise levels defined in (1) was carried out. The audiogram data, assessed according to years of noise exposure from 1 to 52 years, showed

(a) the rate of deterioration of hearing due to loom noise proceeds at a fairly rapid rate for the first 10 to 15 years in the case of the 3000, 4000 and 6000 cps frequencies. Thereafter, deterioration attributable to noise is small, except in the case of 1000 and 2000 cps frequencies where in the latter, further deterioration occurs after 20 to 25 years.

(b) The audiometric data from the two populations studied (the teachers and weavers) have been treated in two ways; first by using Hinchcliffe's presbycusis curves, and secondly by a paired age and noise exposure weaver-teacher combination. Using the Dundee teachers as a control group, high initial losses are seen in the early years of noise exposure (0 to 3 years) in the 2000, 3000 and 4000 cps frequencies.

(c) On the American system for evaluating hearing impairment, 50% of jute weavers after 35+ years loom noise exposure are in the "impaired" zone. In the 32 ears in the 40 to 52 years loom noise exposure group, the 25% (or Q3) percentile is above the limit of hearing without amplification, (46.6) . There is a reduction of everyday personal efficiency, mainly in communication, so that 25% of the subjects are considered to be within the hearing aid category following a life-time of weaving. The mean value of the median hearing levels at 500, 1000 and 2000 cps of a group of retired weavers (mean noise exposure 46 years) falls short (38.4) of the amplification limit but is at the upper limit of impairment as defined by the Academy of Ophthalmology and Otolaryngology of America. There is no Temporary Threshold Shift present. It is suggested, therefore, that on retirement, recovery takes place and that for a true assessment of hearing loss after a life-time of weaving, a six-month noise-free interval is essential. The retired population is better than the active weaving population although with less loom noise exposure.

(4) An attempt was made to assess the social disability of jute female weavers with a mean loom noise exposure of 34 years. Sixty-one (61) per cent practised lip reading, 63% sign language, 75% disliked and could not use the telephone, 49% adjusted their seats in meetings (church etc.) and 46% disliked loud speech or noise (loudness recruitment). The "four average" method of Burns (i.e. average of 500, 1000, 2000 and 3000 cps)

correlated better with the social impairment than the "three average" in current use in America. This situation was foreseen by Davis and Silverman (1965) when they suggested that including the 3000 cps recognised the loss of auditory discrimination which goes with a sharp frequency cut-off at or near 2000 cps. The audiograms of the Dundee weavers are of this type.

(5) Both from the weaver-teacher study and the results of the social impairment survey it is concluded that exposure to weaving noise in the region of 100 dB results in hearing loss which is "moderate" to "severe" after a life time of continuous exposure. The loss should therefore be recognised in this country as a Prescribed Disease under the National Insurance (Industrial Injuries) Act (1946). The nature of the occupation results in a loss of hearing faculty.

(6) Noise surveys carried out in weaving sheds in Dundee at the commencement of the present study (1961-62) and after the completion of the audiometric measurements (1967) showed that new imported looms now being installed to replace obsolete equipment, gave noise levels of double the intensity. The conclusion is that legal control

of overall noise levels of new textile machinery is now necessary if hearing losses of weavers, already severe in the long-exposed groups, are not to become higher.

(7) Although the problem of "weavers' deafness" may be overcome by wearing ear protection, and industrial physicians are active in this field of hearing conservation programmes, ear protective devices have not yet reached the design stage where they are acceptable to all noise-exposed populations especially in hot and humid working environments.

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APPENDIX

APPENDIX

SOUND PRESSURE LEVELS

(S.P.L. re 0.0002 μbar)

TABLE I

(Batching, Carding, Preparing)

No.	Works		A. S.P.	B. S.P.	C. S.P.	Lin. SPL.
1	Camperdown	Sliver Mill	85	88	91	92
		Carding area	85	89	91	92
		Drawing area	84.5	87	88	88.5
2	Manhattan	Drawing area	88.5	89	90	91
		Carding area	89	90	91	91
3	Douglasfield	Breaker No. 6	88.7	93	95.2	95.5
		Spreader area	90.5	93	94.5	95
		Carding area	86.5	90.7	92.6	93.2
		Drawing area	88	90	91	92
4	Heathfield	Breaker area	93	94.5	95.7	96
		Spreader area	93.5	96	98	100
		Bale opener	85	92	95	97
		Dust extraction fan	89	93.5	97.5	98.5
5	Walton	Carding area	89	93	94.5	95.5
		Batching area	92.5	95.5	97.5	98.5
		Drawing area	91	91.5	92	93
6	Stanley	Carding area	89.3	90.5	91.5	92
		Drawing area	88	89	90	91

APPENDIX

SOUND PRESSURE LEVELS

TABLE 2

(Spinning and Winding)

No.	Works	A. S.P.	B. S.P.	C. S.P.	Lin. SPL.
1	CAMPERDOWN				
	Spinning (M/C 75/105)	87	88.5	91	91
	Cop Winding (M/C 95)	102	102	102	103
	Cop Winding (Machie)	81	83	85	86
2	TAY WORKS				
	Winding flat	88	86.5	88.5	90
3	CALDRUM				
	Sliver Spinning	92.5	93	94	94
	Cop Winding	88.5	90	191	92
	Rove Spinning	92.5	94	94.3	94.3
4	BOW BRIDGE				
	Sliver Spinning No.1 East	98	99	99	99
	Sliver Spinning No.2 West	92	93.5	94.5	95
	Cop Winding No.1 East	88	88.5	90.0	90
	Cop Winding No.3 West	91	91.5	93	93.5
	15 Spindle Roll Winding No.4 West	91	91.5	92.5	93
	80 Spindle Roll Winding No.4 West	95	95.5	96	96
	Roll winding and Boyd's Twisters No.2 East	95	96.3	97.2	97.5
	Roll winding and Boyd's Twisters No.2 East	96	97	98.5	99
5	ANGUS				
	Cop winding	107	106.5	196.5	107
	80 Spindle Roll Winding (machine 8)	100	101	101	102

TABLE 2 (contd.)

No.	Works	A. S.P.	B. S.P.	C. S.P.	Lin. SPL.
5	ANGUS				
	15 Spindles Roll winding (machine 15/16)	95	96	96.3	96.5
	Ayrton Precision winding	92.5	94	94.3	95
6	RASHIEWELL				
	Ayrton Precision winding	88	89	89.5	89.5
	Schweitzer cop winding	88	88	89	90
	Fraser Roll winding	89	90	90.5	91
7	WALTON				
	Rove Spinning (M/C 10)	100	101	101	101.5
	Roll Winding (M/C 26/27)	94.5	96.5	96.7	97
	Rove Spinning	98	99	100	100
	Rove Spinning (gear end)	99	100	101	101
	Boyd Twist Frames	94	94	95	95.5
	No. 1 Twist Flat	92	93	94	94.5
	Parker Cop machines	99	99	99	99.5
8	HEATHFIELD				
	Sliver Spinning	96	97	97.5	98
	Sliver Spinning (gear end)	100	101	101	101.5
	Roll winding	88	89	90	91
9	DOUGLASFIELD				
	Sliver Spinning	89.5	91	92	92.5
	Roll winding	88	90.5	92	92.5
	Roll winding (gear end)	92	92.5	92.5	95.5
	Low cop winders	86	87	88	89

TABLE 2 (contd.)

No.	Works	A. S.P.	B. S.P.	C. S.P.	Lin. SPL
10	MANHATTAN				
	Sliver Spinning	91	92	92.5	93
	Cop winding	89	89.5	89.5	90
	80 Spindle rol winding	87.5	88	89	89.5
	FORFAR				
	Pirn winding	91.5	92.5	93	94
	Cone winding	84.5	85	85.5	86
11	STANLEY				
	Hall cop winding	92.5	93.5	94	94.5
	No.3 Mid Mill R.F.N.S.	89.5	91	92	93
	No.2 Mid Mill Carding Pass				
	A 12D Frame	88	89	90.3	91
	AK P.12D Frame	85	88	89	90
	East Mill No.3 Arundels	85	87	88	90
	East Mill No.2 Spinning	92	93	94	94
	East Mill No.1 S.D.T.	98	99	99.5	100
	East Mill G.Holt W.D.R.S.	87	89	90.5	93.5
12	BRECHIN				
	Spool winding	84	85.5	86	87

SOUND PRESSURE LEVELS

TABLE 3

(Weaving)

No.	Works	A. S.P.	B. S.P.	C. S.P.	Lin. SPL.
1	CAMPERDOWN				
	'C' Range 5 yd Northrop	93	93	93.5	94
	'C' Range 4 yd Pass 265	96	96.5	96.5	97
	Upper Factory Centre of Shed	99.5	100	100.5	100.5
	S.E. Corner of Shed	98.5	99	99	99
	Lower Factory 4 yd area	95.5	96	96.5	96.5
	Pass Looms 28/32 63"	98.5	99.0	99.5	100.0
	Pass Looms 25/40 43"/63"	99.0	99.5	100.5	101.0
	Pass Looms 498/500 4 yd	98.5	99.0	99.5	100.0
	Pass Looms 561/565 4 yd	98.0	99.0	100	100.0
2	TAY CARPETS				
	Brussel Shed	91	92	92	93
	Loom Platform	95	95	95	95
	Carpet Weaving M.3	98	99	99.5	99.5
3	CALDRUM				
	Weaving (4 yd)	98.5	99.5	100	100.5
	Weaving (5 yd)	96.5	97.5	97.5	98
4	BOW BRIDGE				
	Factory Loom 100" Northrop	98.5	98.5	99	99
	Factory Main Pass	98.3	98.5	99	99
	Factory Loom 105/106 ULRO 4 yd	99	99	99.5	100
	Factory Loom 153/154 ULRO 88"	99	99	93.5	99.5

TABLE 3 (contd.)

No.	Works	A. S.P.	B. S.P.	C. S.P.	Lin. SPL.
5	MANHATTAN				
	Circular Looms Weaving area	90	91	92	93
	Circular Looms Roll up area	91.5	94	94	94
	FORFAR				
	Weaving 5 yd Northrop	92	93	94	94.5
	Weaving 5 yd ULRO	93	94	95	95
6	MAXWELLTOWN				
	Weaving Tumack	86	87	88	88
	Weaving 68"	99	100	100	100.5
7	John Lawson Jnr. Forfar				
	Weaving 85" Jacquard	96	96	97	98
	Weaving 32" Loom	98	99	99	100
	Weaving 60" Dobby	95	95.3	96	96
	Weaving 5 yd ULRO	93.5	94.5	95	96
8	D. and R. Duke, Brechin				
	Large Shed Looms 9/10/11/12 32" Jacquard	100	100.5	102	102.5
	Weaving Loom 98	98	99	100.5	101.5
	Weaving 4 yd Northrop 47/48	94.5	95	95	96
	Weaving Looms 47/48/49/150 (gear ends)	98.3	99	99	99.5
	Single Training Loom	93	93.5	94	94.5
9	STANLEY				
	Weaving Great Easterner	102	103	103	103.5
	Weaving Hall Looms (2)	98	98.5	99	99
	Weaving Hall Loom No.10	94	94.5	95	96
	Weaving Narrow Belt Loom	97	97	98	98.5

TABLE 3 (contd.)

No.	Works	A. S.P.	B. S.P.	C. S.P.	Lin. SPL
10	CARNOUSTIE				
	Weaving 43"/63"	98	99	100.5	101.5

APPENDIX

SOUND PRESSURE LEVELS

TABLE 4

(Calender)

No.	Works	A. S.P.	B. S.P.	C. S.P.	Lin. SPL.
1	CAMPERDOWN				
	Calender area	76	78	82	82
	Cropping Machine	100	100	100	100
	Calender Office	72	74	76	78
	Surgery and Treatment room	64	66	67	74
2	BOW BRIDGE				
	Extraction Fan (SELLERS) at 20 feet radius.	92	97.5	100.5	101.5
	Cropper No.2 adjacent to fan	95	97	98	100
	Cropper No.1	87	89	92	93
	Two Calenders	86	88	90	90
	Rolling	91	92	94	94.5
	Ambient Noise in Building	81	83	85.5	87
3	J. Lowson Jnr., Forfar				
	Mangle	84	86	88	88
	Cropper	82	84	85	86
	Measuring Machine	86.5	88.5	89	90

TABLE 5

Weaving Sound Pressure Levels According to Type of Loom

Loom Type or size	Average S.P.L. (dB)
Great Eastern	103.5
43"	102
63"	101
3 yd	100.5
4 yd	99
5 yd Northrop) ULRO)	95.96
Circular	93
Tumack	88

Table 6

Maximum Permissible Noise in Audiometric Enclosure for Measurement of -10 dB Hearing Level

requency (cps)	Threshold SPL BS 2497 (dB)	Threshold SPL* for -10 dB hearing level (dB)	Max.permissible SPLx for -10 dB hearing level (dB)	Max.permissible SPL for -10 dB hearing level (dB)	Attenuation MX41/AR TDH39 (dB)	Max.permissible SPL in Booth (dB)
125	30	20	10	10	2	12
250	19	9	-1	2	4	6
500	12	2	-8	-3	11	8
1000	9	-1	-11	-5	21	16
2000	11	1	-9	-3	29	26
3000	7.5	-2.5	-12.5	-6.5	36	29.5
4000	9.5	-0.5	-10.5	-4.5	33	28.5
6000	14	4	-6	0	30	30
8000	18.5	8.5	-1.5	3.5	21	24.5

* per critical band

x per octave band

APPENDIX

Table 29

Mean and Standard Deviation (dB) for Each Age Group and Frequency

Frequency (kc/s)	Ear	Age Group (yrs)														
		18-24			25-34			35-44			45-54			55-64		
		No. of Ears	Mean (dB)	S.D.	No. of Ears	Mean (dB)	S.D.	No. of Ears	Mean (dB)	S.D.	No. of Ears	Mean (dB)	S.D.	No. of Ears	Mean (dB)	S.D.
0.125	Right	46	2.66	4.52	33	2.31	4.15	29	4.27	4.60	35	6.25	7.23	26	5.29	3.88
	Left	46	0.60	4.49	33	0.80	5.32	29	2.80	3.23	35	2.89	5.78	26	4.13	4.45
	Both	92	1.63	4.60	66	1.55	4.79	58	3.53	4.01	70	4.57	6.71	52	4.71	4.18
0.25	Right	46	0.05	4.17	33	0.57	3.82	29	0.99	3.68	35	3.32	5.99	26	3.94	3.23
	Left	46	-1.14	4.01	33	0.04	4.81	29	0.22	3.38	35	2.11	5.72	26	1.92	4.33
	Both	92	-0.54	4.12	66	0.30	4.31	58	0.60	3.52	70	2.71	5.84	52	2.93	3.92
0.5	Right	46	-0.98	4.12	33	0.34	3.30	29	0.65	2.81	35	2.82	5.49	26	3.37	2.89
	Left	46	-2.93	3.34	32	-1.17	4.38	29	-0.65	3.64	35	1.75	4.24	26	2.60	4.20
	Both	92	-1.96	3.86	65	-0.40	3.91	58	0.00	3.29	70	2.29	4.90	52	2.98	3.59
1	Right	46	-3.37	3.65	33	-1.86	4.05	29	-2.11	3.22	35	1.68	4.94	26	0.77	4.06
	Left	46	-4.02	3.26	32	-2.89	3.51	29	-2.11	3.36	35	-0.18	4.75	26	1.15	4.03
	Both	92	-3.70	3.46	65	-2.37	3.80	58	-2.11	3.26	70	0.75	4.90	52	0.96	4.01
2	Right	46	-1.90	3.14	33	0.19	4.33	29	0.13	3.10	35	2.61	6.01	26	3.85	5.22
	Left	46	-2.17	3.39	32	-1.56	4.52	29	1.08	5.47	35	3.61	6.70	26	4.04	6.87
	Both	92	-2.04	3.25	65	-0.67	4.48	58	0.60	4.43	70	3.11	6.34	52	3.94	6.04

(contd.)

Frequency (kc/s)	Ear	Age Group (yrs) 18-24			25-34			35-44			45-64			55-64		
		No. of Ears	Mean (dB)	S.D.	No. of Ears	Mean (dB)	S.D.	No. of Ears	Mean (dB)	S.D.	No. of Ears	Mean (dB)	S.D.	No. of Ears	Mean (dB)	S.D.
3	Right	46	-2.01	3.49	33	-0.95	3.74	29	1.08	3.40	35	4.04	6.85	26	5.38	5.83
	Left	46	-2.34	3.75	32	-2.03	3.94	29	1.77	5.40	35	6.61	7.18	26	7.40	7.72
	Both	92	-2.17	3.61	65	-1.48	3.85	58	1.42	4.49	70	5.32	7.09	52	6.39	6.85
4	Right	46	-2.75	3.91	33	-1.10	4.84	29	2.37	5.11	35	5.61	6.92	26	9.04	9.44
	Left	46	-2.55	4.27	32	-1.88	3.81	29	4.01	8.97	35	9.96	9.06	26	11.25	9.14
	Both	92	-2.65	4.07	65	-1.48	4.35	58	3.19	7.29	70	7.79	8.30	52	10.14	9.27
6	Right	46	0.22	4.43	33	1.25	5.38	29	6.16	6.49	35	14.46	11.80	26	19.90	11.67
	Left	46	-1.14	4.94	33	0.27	4.19	29	8.04	6.63	35	17.81	12.80	26	20.10	12.47
	Both	92	-0.46	4.72	66	0.76	4.81	58	7.10	6.57	70	16.14	12.33	52	20.00	11.96
8	Right	46	0.76	4.37	33	1.92	4.61	29	9.27	7.54	35	19.39	13.64	26	25.38	14.09
	Left	46	-0.76	4.73	33	1.10	5.52	29	9.01	6.66	35	21.88	17.21	26	26.15	12.85
	Both	92	0.00	4.59	66	1.51	5.06	58	9.14	7.05	70	20.64	15.47	52	25.77	13.36

APPENDIX

Table 30

Estimated Noise-induced Threshold Shift
(Expressed as 25th percentile, median and 75th percentile in dB)
of Group 1, classified by duration of exposure. (Dundee weavers)

Noise exposure completed years	Number of ears	Frequency (cps)								
		125	250	500	1000	2000	3000	4000	6000	8000
1	43	-1.5 1.0 4.5	-0.7 1.8 4.2	-0.3 2.5 4.6	-1.6 0.0 3.8	-1.5 1.7 3.8	-1.4 0.5 4.4	3.0 6.3 14.2	-0.6 4.6 13.0	-4.7 -0.3 4.9
1 - 2	50	-1.5 0.8 4.4	-1.5 -0.3 3.0	-1.2 0.3 2.1	-2.1 -1.0 0.3	-1.6 -0.3 2.8	1.5 4.3 12.6	4.7 14.8 25.6	4.1 10.3 20.2	-1.0 5.0 12.1
3 - 4	42	2.2 5.9 9.4	-0.1 4.1 7.3	-0.7 2.3 8.7	-1.4 2.3 4.3	-0.3 3.8 9.1	-0.1 9.1 19.5	9.2 18.4 35.2	2.8 13.2 24.9	-3.9 4.0 22.1
5 - 9	59	4.4 9.4 14.7	2.9 7.8 10.0	1.3 5.0 9.5	-1.1 2.7 8.5	3.7 8.5 13.8	9.0 17.9 37.5	18.0 29.4 41.9	8.0 18.0 33.0	3.4 9.7 23.0
10 - 14	44	11.9 16.8 19.7	8.2 12.7 18.4	4.6 9.8 14.4	4.1 8.3 13.0	10.6 18.1 23.9	24.4 37.7 44.9	33.5 42.0 47.4	15.6 21.4 31.4	6.9 12.0 18.6

(contd.)

Noise Exposure completed years	Number of ears	Frequency (cps) 125	250	500	1000	2000	3000	4000	6000	8000
15 - 19	53	6.3	7.7	4.9	3.2	10.1	23.8	33.8	19.3	5.2
		11.1	9.8	8.6	8.0	16.0	39.1	44.5	29.7	14.3
		16.7	14.6	12.8	13.8	24.6	49.4	54.0	40.7	25.1
20 - 24	32	5.1	5.9	4.1	2.6	6.1	22.7	30.6	18.2	9.1
		10.4	8.8	8.6	8.5	15.6	38.8	44.4	33.8	18.6
		14.4	14.8	14.2	16.9	36.9	45.9	49.9	44.1	29.9
25 - 29	39	5.7	6.5	7.5	5.8	14.5	38.8	41.7	28.0	13.0
		11.4	12.5	12.0	15.8	22.5	44.4	47.1	35.1	26.1
		17.2	18.3	17.5	22.5	45.0	52.5	57.5	45.5	36.3
30 - 34	40	0.3	1.5	2.8	1.8	19.1	40.2	44.1	26.1	11.0
		5.8	6.4	7.1	10.6	39.6	50.1	48.8	39.3	22.6
		16.5	12.4	11.9	26.9	49.7	55.2	52.4	50.3	42.4
35 - 39	27	10.0	7.5	8.8	8.8	38.0	42.5	42.5	31.5	13.0
		15.5	15.0	15.0	12.5	48.3	51.4	50.7	40.5	31.8
		21.9	21.6	20.0	26.3	53.6	56.1	57.0	51.5	46.1
40 - 52	32	8.5	9.1	8.6	15.6	35.8	41.9	45.1	28.1	15.7
		11.8	14.1	14.5	24.6	45.9	50.5	50.2	38.5	22.7
		22.7	21.5	21.7	34.8	52.9	55.5	55.3	48.9	36.1

Table 31

Median Estimated Noise-Induced Threshold Shift
Retired weavers (Group 2) compared with Hinchcliffe's age-matched rural population

	Number of ears	Frequency (cps) 125	250	500	1000	2000	3000	4000	6000	8000
Hearing levels (median, dB) of Group 2 compared with control population										
Group 2	32	30.4	28.1	26.9	35.8	52.5	59.8	65.3	60.9	56.0
Control population*	47	10.1	9.6	9.7	12.8	14.6	19.8	22.2	33.9	42.2
Estimated noise-induced threshold shift (median, dB)										
Group 2		20.3	18.5	17.2	23.0	37.9	40.0	43.1	27.0	13.8

* From Hinchcliffe

Table 32

Mean Differences in Threshold (dB) between Weavers and Teachers

GROUP 1 : Less than 1 year Loom Noise Exposure : No. of pairs - 15

Frequency K.Hertz	Mean Differences (dB) Weavers-Teachers				Variance			
	R	L	R-L	Av.	R	L	Av.	S.E.
0.25	2.8	3.7	-0.84	3.2	90.1	38.3	64.2	1.46
0.50	4.7	6.8	-2.2	5.7	87.4	41.5	64.4	1.47
1	5.3	7.5	-2.2	6.4	79.3	64.3	71.8	1.55
2	4.0	5.8	-1.8	4.9	58.7	58.6	58.7	1.40
3	8.3	7.5	0.83	7.9	82.7	100.0	91.4	1.75
4	14.3	12.8	1.5	13.6	99.5	129	114	1.95
6	10.3	13.8	-3.5	12.1	186	125	156	2.28
8	5.2	8.2	-3.0	6.7	129	163	146	2.21

S.E. = Standard Error

L = Left Ear   Av. = Average   R = Right Ear

Mean Difference in Threshold (dB)
between Weavers and Teachers

GROUP 2 : 1 - 2 years Loom Noise Exposure : No. of pairs - 10

	Mean Differences (dB) Weavers-Teachers				Variance			
Frequency K.Hertz	R	L	R-L	Av.	R	L	Av.	S.E.
0.25	3.2	4.2	-1.0	3.7	65.3	68.1	66.7	1.83
0.50	4.5	6.0	-1.5	5.2	33.1	40.6	36.8	1.36
1	5.2	7.0	-1.7	6.1	39.5	48.3	43.9	1.50
2	3.2	2.7	0.5	3.0	29.2	43.7	36.5	1.35
3	8.0	6.0	2.0	7.0	48.3	44.7	46.5	1.53
4	14.6	11.5	3.6	13.1	225	146	186	3.05
6	14.0	15.7	-1.7	14.9	208	71.0	140	2.64
8	5.7	10.0	-4.25	7.9	37.6	52.8	45.2	1.50

S.E. = Standard Error

Mean Difference in Threshold (dB)
between Weavers and Teachers

GROUP 3 : 3 - 4 years Loom Noise Exposure : No. of pairs - 12

Mean Differences (dB) Weavers-Teachers					Variance			
Frequency K.Hertz	R	L	R-L	Av.	R	L	Av.	S.E.
0.25	1.7	0.0	1.7	0.8	28.8	35.2	32.0	1.15
0.50	2.1	3.5	-1.5	2.8	30.5	34.6	32.5	1.16
1	3.7	1.0	2.7	2.4	26.7	30.1	28.4	1.10
2	6.2	6.4	-0.2	6.3	173	66.4	69.9	1.71
3	12.1	14.0	-1.9	13.0	256	314	285	3.45
4	19.0	23.3	-4.4	21.1	404	354	379	3.97
6	17.9	17.9	0.0	17.9	303	263	283	3.44
8	15.6	11.7	3.96	13.6	234	254	242	3.18

S.E. = Standard Error

Mean Differences in Threshold (dB)
between Weavers and Teachers

GROUP 4 : 5 - 9 years Loom Noise Exposure : No. of pairs - 20

Mean Differences (dB) Weavers-Teachers					Variance			
Frequency K.Hertz	R	L	R-L	Av.	R	L	Av.	S.E.
0.25	6.4	7.1	-0.7	6.8	60.8	49.5	35.2	0.94
0.50	6.5	7.4	-0.9	6.9	36.4	39.8	38.1	0.98
1	8.0	6.9	1.1	7.4	47.1	43.3	45.2	1.06
2	13.5	11.7	1.7	12.6	133	95.0	114	1.69
3	23.2	25.0	-1.7	24.1	228	328	278	2.64
4	32.0	35.0	-3.0	33.5	282	192	244	2.47
6	26.6	26.5	0.13	26.6	276	207	241	2.46
8	17.0	19.9	-2.85	18.5	261	321	294	2.71

S.E. = Standard Error

Mean Differences in Threshold (dB)
between Weavers and Teachers

GROUP 5 : 10 - 14 years Loom Noise Exposure : No. of pairs - 20

Mean Differences (dB) Weavers-Teachers					Variance			
Frequency K.Hertz	R	L	R-L	Av.	R	L	Av.	S.E.
0.25	11.2	11.5	-0.3	11.4	60.2	70.7	65.4	1.28
0.50	9.4	10.2	-0.9	9.8	35.4	44.1	39.8	1.00
1	9.4	11.5	-2.1	10.4	30.2	50.9	40.5	1.01
2	15.9	15.1	0.8	15.5	113	121	117	1.71
3	34.0	34.6	-0.6	34.3	319	259	279	2.64
4	44.1	40.0	4.1	42.1	265	258	261	2.56
6	26.4	28.6	-2.2	27.5	268	282	275	2.62
8	14.2	15.1	-0.9	14.7	235	242	238	2.44

S.E. = Standard Error

Mean Differences in Threshold (dB) between Weavers and Teachers

GROUP 6 : 15 - 19 years Loom Noise Exposure - No. of pairs - 17

	Mean Differences (dB) Weavers-Teachers				Variance			
Frequency K.Hertz	R	L	R-L	Av.	R	L	Av.	S.E.
0.25	11.5	14.0	-2.5	12.7	41.4	81.3	61.4	1.34
0.50	9.1	12.8	-3.7	11.0	35.1	56.2	45.6	1.16
1	13.8	13.2	0.6	13.5	156	147	152	2.11
2	22.3	20.5	1.8	21.4	250	223	237	2.64
3	45.4	39.7	5.7	42.6	292	327	309	3.02
4	52.3	45.6	6.7	49.0	204	293	249	2.71
6	34.3	29.8	4.5	32.0	307	282	294	2.94
8	17.1	18.1	-1.0	17.6	285	218	251	2.72

S.E. = Standard Error

Mean Differences in Threshold (dB)
between Weavers and Teachers

GROUP 7 : 20 - 24 years Loom Noise Exposure : No. of pairs - 14

	Mean Differences (dB) Weavers-Teachers				Variance			
Frequency K.Hertz	R	L	R-L	Av.	R	L	Av.	S.E.
0.25	11.2	11.2	0.0	11.2	64.2	35.3	49.8	1.33
0.50	10.0	9.6	0.4	9.8	76.0	62.4	69.2	1.57
1	11.6	10.0	1.6	10.8	83.3	106	94.5	1.84
2	18.7	24.3	-5.5	21.5	393	399	396	3.76
3	33.6	40.4	-6.9	40.0	364	354	359	3.58
4	44.8	48.0	-3.2	46.4	255	252	254	3.01
6	33.0	36.1	-3.1	34.5	226	280	253	3.01
8	18.2	18.2	0.0	18.2	287	408	347	3.5

S.E. = Standard Error

<u>Mean Differences in Threshold (dB)</u>
<u>between Weavers and Teachers</u>

GROUP 8 : 25 - 29 years Loom Noise Exposure : No. of pairs - 11

Mean Differences (dB) Weavers-Teachers					Variance			
Frequency K.Hertz	R	L	R-L	Av.	R	L	Av.	S.E.
0.25	14.1	16.6	-2.5	15.3	149	319	234	3.26
0.50	14.5	18.2	-3.7	16.4	190	371	280	3.57
1	21.6	24.5	-2.9	23.0	315	378	350	3.99
2	34.3	33.4	0.9	33.9	378	192	285	3.60
3	47.3	40.2	7.04	43.7	157	174	166	2.74
4	48.4	44.1	4.3	46.2	208	248	227	3.22
6	35.7	34.3	1.4	35.0	314	303	308	3.74
8	21.6	18.7	2.9	20.1	538	527	532	4.92

S.E. = Standard Error

Mean Differences in Threshold (dB)
between Weavers and Teachers

GROUP 9 : 30 - 34 years Loom Noise Exposure : No. of pairs - 17

	Mean Differences (dB) Weavers-Teachers				Variance			
Frequency K.Hertz	R	L	R-L	Av.	R	L	Av.	S.E.
0.25	7.9	9.4	-1.5	8.7	147	163	153	2.14
0.50	9.7	10.0	-0.3	9.9	126	150	138	2.02
1	15.3	16.2	-0.9	17.5	273	331	302	2.98
2	38.7	34.4	4.3	36.5	451	488	469	3.72
3	48.2	44.3	3.9	46.2	254	292	273	2.83
4	54.3	46.8	7.5	50.5	141	165	153	2.12
6	36.8	31.1	5.7	33.9	394	356	375	3.32
8	17.3	13.7	3.6	15.5	516	530	520	3.91

S.E. = Standard Error

Mean Differences in Threshold (dB) between Weavers and Teachers

GROUP 10 : 35+ years Loom Noise Exposure : No. of pairs - 19

Mean Differences (dB) Weavers-Teachers					Variance			
Frequency K.Hertz	R	L	R-L	Av.	R	L	Av.	S.E.
0.25	19.6	19.6	0.0	19.6	136	181	158	2.04
0.50	20.7	18.7	2.0	19.7	147	149	148	1.97
1	29.2	25.5	3.7	27.4	315	366	341	3.00
2	46.7	41.8	4.9	44.3	246	583	415	3.30
3	53.9	49.2	4.7	51.6	206	333	270	2.66
4	56.2	54.5	1.7	55.7	225	249	237	2.50
6	39.1	37.6	1.5	38.4	394	579	487	3.58
8	27.0	20.1	6.9	23.6	465	843	654	4.15

S.E. = Standard Error

QUESTIONNAIRE ON HEARING

A. General Particulars

Survey or hospital ...... Serial or Hospital No....

Interviewer (if not self-answered) ....

Today's date ....

B. Personal Particulars

Name .... (Surname) Sex .... (1)

.... (First Names) D.of B. ..... (2)

Address ....

....

C. Current Noise Exposure

1. What is your job? (3)

2. At any time in this job, is it so noisy that you ever have to raise your voice to be heard? (4)

If yes,

For how many hours of the week is this so? (5)

How long have you been in this job? (yrs) (6)

Do you ever wear any ear protection? (7)

If yes,

Always or sometimes? (8)

What ear protectors do you use? Cotton wool; Ear plugs; Head band type Other (strike out type not applicable) (9)

D. Previous Occupational Noise Exposure (excluding military service)

Prior to your present job, have you ever worked in a noisy job where you had to raise your voice to be heard? (10)

If yes

Did you work in a noisy job for more than one year? (11)

D. (contd.)

What jobs and for how long? (12)

(Please give year of starting particular job, and year of finishing)

Did you use ear protectors? (13)

If yes,

Always or sometimes? (14)

What ear protectors did you use? (15)

Cotton wool; Ear plugs; Head band type; Other (strike out type not applicable)

E. Acoustic Trauma

Have you ever used a rifle or other gun or served in a gun crew? (16)

If yes, specify which of the following guns you have used and how many rounds you have fired:

Gun	No, of rounds fired in life-time	
0.303 calibre rifle		(17)
12 bore rifle		(18)
0.22 calibre rifle		(19)
machine guns		(20)
Artillery		(21)
Other (specify)		(22)

Did you use any ear protectors? (23)

If yes

Always or sometimes? (24)

Do you/did you have any noises in the ears immediately after firing a gun? (25)

F. Most Recent Noise Exposure

(If you ever had to raise your voice to be heard because working conditions were so noisy)

How long is it since you were working in conditions that were so noisy? (26)

F. (Contd.)

What was the duration in hours of this particular noise exposure. (27)

Did you use any ear protectors? (28)

G. <u>Other Audiologic Hazards</u>

Have you ever had/do you ever have pains in the ears? (29)

If yes

(i) When? (30)

(ii) Which ear? (31)

Have you ever had/do you have running ears, discharge from, or abscesses in, the ears? (32)

If yes

(i) When? (33)

(ii) Which ear? (34)

Have you ever had an injury to the ear? (35)

If yes

(i) What? (36)

(ii) When? (37)

(iii) Which ear? (38)

Have you ever had an operation on the ear or the mastoid, or has the ear-drum been punctured? (39)

If yes

(i) When? (40)

(ii) What? (41)

(iii) Which ear? (42)

Have you ever had an injury to the head which made you unconscious? (43)

If yes

(i) When? (44)

(ii) For how long were you unconscious? (45)

G. (contd.)

Do you have noises (for example, "singing" "ringing" or "hissing") in the ears or head? (46)

If yes

When did these noises first start? (47)

Which ear is affected? Right and/or Left (48)

And are the noises (i) troublesome? (49)

or (ii) not troublesome? (50)

Are the noises present

(i) all the time? (51)

or (ii) "on-and-off"? (52)

If the noises are present all the time, Do they vary in loudness? (53)

If the noises are present "on-and-off" only, How often do they come on an average? (54)

Yearly/monthly/weekly/daily

Do you suffer, or have you ever suffered, from one or more than one attack of giddiness or dizziness (i.e. you had an actual sensation of the room or yourself going round or moving)? (55)

If yes

When did this/these attack(s) start? (give year) (56)

Have you had more than one attack? (57)

Do these attacks last (i) for no more than a second? (58)

or (ii) for at least a minute? (59)

Are these attacks brought on

(i) by moving the head? (60)

or (ii) by rising from a stooping or sitting position? (61)

G. (contd.)

Are these attacks accompanied by

(i) a feeling of sickness? (62)

(ii) vomiting? (63)

(iii) a pressure sensation in one or both ears? (64)

(iv) loss of consciousness? (65)

or (v) noises in one or both ears? (66)

To your knowledge, have you ever had injections of streptomycin? (67)

If yes

(i) When? (68)

(ii) For how long? (69)

(iii) Were the injections followed by:

(a) difficulty in focussing with the eyes? (70)

or (b) unsteadiness in walking? (71)

To your knowledge, have you ever had quinnine? (72)

If yes

(i) When? (73)

(ii) How long for? (74)

(iii) Did it produce noises in the ears? (75)

Have you had any of the following illnesses?

Mumps (76)

Meningitis (77)

Malaria (78)

Do or did any of the following relatives suffer from deafness?

Mother (79)

Father (80)

Sister(s) (81)

Brother(s) (82)

G. (contd)

Mother's sister(s)	(83)
Mother's brother(s)	(84)
Father's sister(s)	(85)
Father's brother(s)	(86)

If there is a particular incident of any sort which you think might have damaged your hearing (for example, an explosion, a blow on the ear, or such like) please describe the incident, mentioning how long ago it happened. (87)

H. Present State of Hearing

Do you at all times hear normally? (except when you have a "cold") (88)

If no

When did you first notice any trouble with your hearing? (give year) (89)

Did the difficulty in hearing come on:

(i) gradually (90)

(ii) suddenly (91)

Is the hearing (i) sometimes normal? (92)

(ii) never normal but better at sometimes than at other times? (93)

(iii) getting worse? (94)

(iv) neither getting better nor worse? (95)

Do you have difficulty in hearing when a group of people are talking? (96)

Do you have difficulty with person-to-person conversation? (97)

Is there any distortion of sound? (98)

Can you hear better or worse in noisy surroundings? (99)

Can you have the radio too loud? (100)

H. (contd.)

Do you have difficulty in deciding which direction sounds are coming from? (101)

Do you wear a hearing aid? (102)

If so, is it (i) satisfactory? (103)

(ii) unsatisfactory? (104)

(iii) the "Medresco" (govt) aid? (105)
or a commercial aid? (106)

I. Previous Hearing Tests

Have you ever had your hearing tested with a machine before? (107)

If yes (i) When? (108)

(ii) Where? (109)

(iii) Why? (110)

J. Nose

Do you have a "cold" at the moment? (111)

Do you suffer from hay fever? (112)

Do you suffer from a thick, yellow discharge from the nose, and have you done so for at least one year? (113)

APPENDIX B

SOCIAL ASPECTS OF HEARING LOSS : PART I - OCCUPATIONAL and SOCIAL

* *

NAME .... SERIAL NUMBER ....

ADDRESS .... SEX : Male 1
Female 2

....

DATE OF BIRTH .... AGE ....

MARITAL STATUS: Married 1, Single 2, Widowed 3, Other 4

RESIDENCE: Always urban 1, Always rural 2, Mixed 3

OCCUPATION: ....

Started work: age ... Retired, age ...
"working life" ...

Time off: War ... Other jobs ... Family...

Time at job ... (check that working life accounted for)

Do you/did you wear ear protectors at work?
Yes 1, No 0

SUMMARY: Main Occupation ....

Total time in the occupation (yrs)

Time off (exclude normal holidays)

RETIREMENT (omit if still employed)

How long have you been retired? (check with retiral age)

Part-time work during retirement:

Yes, noise 1; Yes, no noise 2; No 0

EXTRANEOUS NOISE EXPOSURE

Have you ever worked in a noisy job other than ...?

If yes, which? ....

How long were you in this job? ....

Have you ever used a shotgun or rifle? ....

If yes, how often and for what length of time? ....

War: were you involved with gunfire, bombing, explosions, etc. during war service or as a civilian? ....

SOCIAL

HOUSEHOLD: Lives alone 1, with parents 2, with sib(s) 3, with family 4.

REACTIONS OF OTHER PEOPLE: Do the people at home complain that you are deaf?

No 0, Yes 1, Sometimes 2, N.A. 3

COMMUNICATION:

Do you have difficulty talking with:

(a) family and friends - in a quiet place ...
when other people are talking ....
in a noisy place ....
e.g. train, bus, machinery

(b) strangers - in a quiet place ...
when other people are talking ....
in a noisy place ...

SUMMARY (to be coded later)

Do people annoy you by shouting to make you hear?
No 0, Yes 1, Sometimes 2, N.A. 0

Do you lip read? No 0, At work 1, All time 2

Do you use sign language?
No 0, At work 1, All time 2

TELEPHONE: Do you have a telephone? No 0, Yes 1

Can you easily understand people on the telephone?
No 0, Yes 1, Sometimes 2, N.A. 9

If not, why not? ....

RADIO: Do you like volume high? No 0, Yes 1
Don't listen 9

If you don't listen, why? ....

Do you like volume higher than other members of the household? No 0, Yes 1, Sometimes 2, N.A. 9

Do they ever turn volume down? (code above)

TELEVISION: Do you like volume high? (code as radio)

If you don't listen, why? ....

Do you like volume higher than other members of the household? (code as radio)

PUBLIC MEETINGS:

At meetings, church, cinema, theatre, bingo, do you hear clearly if you have to sit at back? ....

Where do you normally like to sit? ....

Have you changed your usual seat? ....

SUMMARY (to be coded later)

GENERAL:

How is your hearing at present? ....

(suggest: slightly hard of hearing, hard of hearing etc.)

If not normal:

When did you first notice a change? ....

How long had you been in noise? ....

Do you have a hearing aid? ...... Type ....

Do you use it? ..... If not, why not? ....

....

How does being .... affect your life?

....

INTERVIEWER ....

DATE ....

COMMENTS: Interviewer's assessment of hearing.

SOCIAL ASPECTS OF HEARING LOSS : PART II - MEDICAL and AUDIOMETRIC

* *

NAME .... SERIAL NUMBER ....

ADDRESS .... SEX: Male 1
Female 2

.... AGE ....

MEDICAL HISTORY:

AURAL DISEASE: State in each case the ear(s) involved and when the events occurred.

Have you ever had/do you ever have any of the following:

Pain in ear

"Running" ear, discharge, abscesses

Injury to ear

SUMMARY (to be coded by medical examiner)

None 0, Negligible 1, Positive 2

CONCUSSIVE HEAD INJURY:

Have you ever had a head injury which resulted in unconsciousness?

Yes 1, No 0

VERTIGO AND TINNITUS:

Have you ever had singing, ringing or hissing in ears?

Have you ever had giddy or dizzy turns?

If so, are these attacks accompanied by:

Sickness, Noise in ears?

SUMMARY (to be coded later)

OTHER RELEVANT DISEASES:

Mumps with ear involvment, malaria, meningitis, tuberculosis.

DRUGS: Quinnine, streptomycin

UPPER RESPIRATORY TRACT INFECTION:

Have you a cold at the moment or discharge from nose?

MEDICAL EXAMINATION:

EARDRUMS: Normal, perforation, scars ....

PATHOLOGY: Normal, Otosclerosis, Meniere's Disease

WAX: Right - None, negligible, present

Left - None, negligible, present

TESTS:	RHINNE	Positive	Negative
	WEBER	Positive	Negative

OVERALL MEDICAL SUMMARY:

Accepted: Rejected - Pathology

Injury

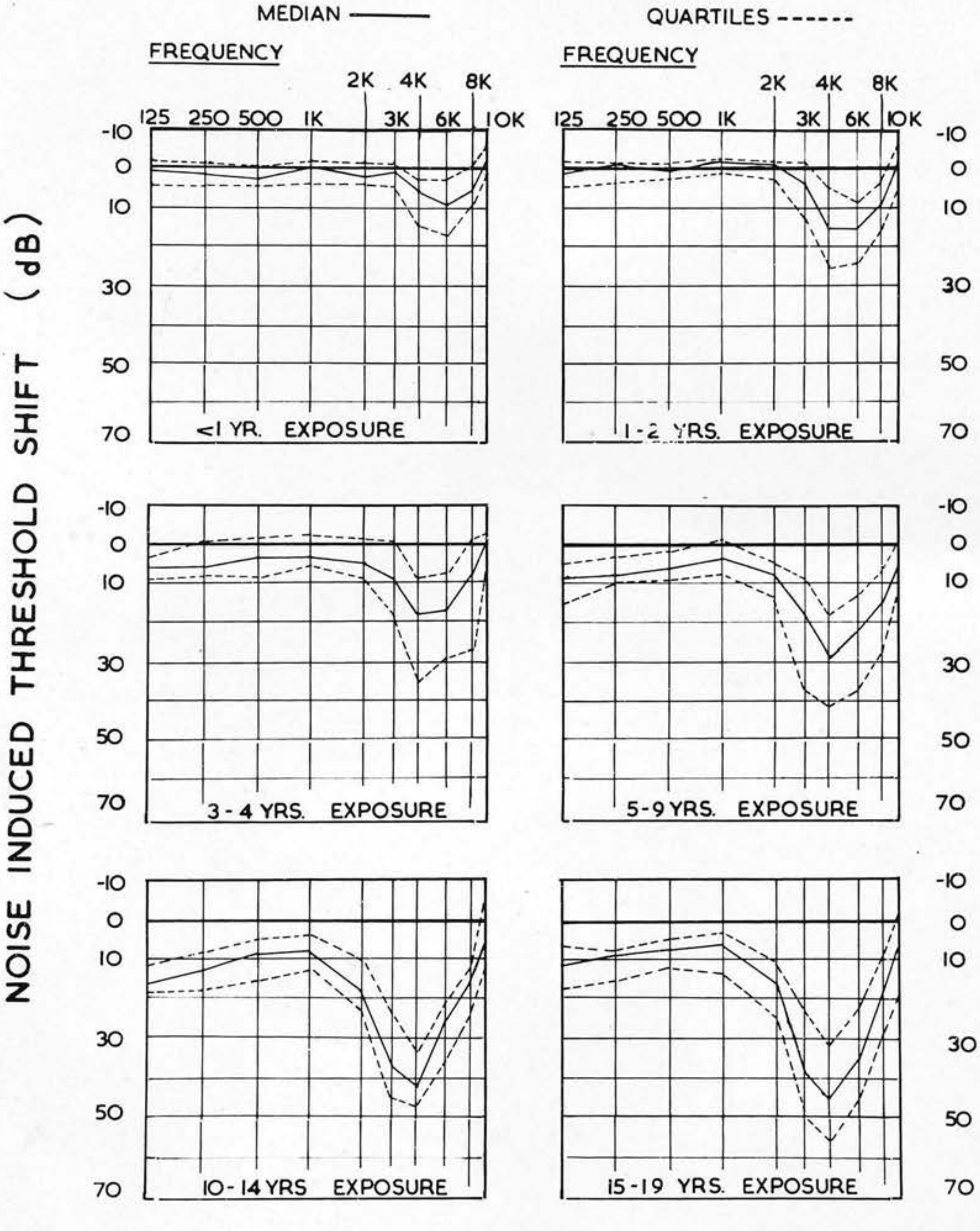
History of infection

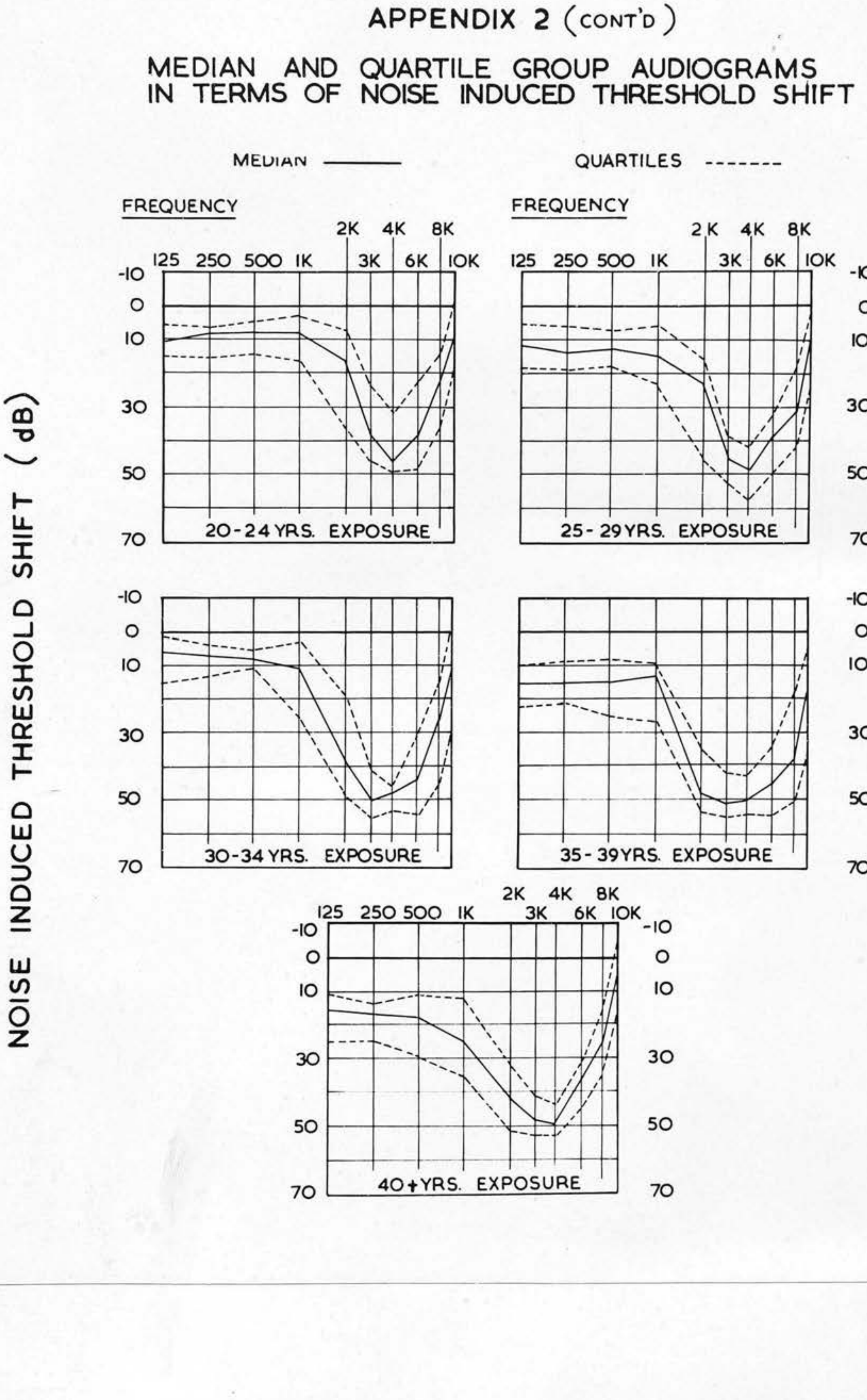
U.R.T.I.

Other

APPENDIX 2

MEDIAN AND QUARTILE GROUP AUDIOGRAMS IN TERMS OF NOISE INDUCED THRESHOLD SHIFT




APPENDIX 2 (CONT'D)
MEDIAN AND QUARTILE GROUP AUDIOGRAMS IN TERMS OF NOISE INDUCED THRESHOLD SHIFT
MEDIAN
QUARTILES
FREQUENCY
125 250 500 1K 2K 3K 4K 6K 8K 10K
NOISE INDUCED THRESHOLD SHIFT (dB)
-10 0 10 30 50 70
20-24 YRS. EXPOSURE
25-29 YRS. EXPOSURE
30-34 YRS. EXPOSURE
35-39 YRS. EXPOSURE
40+ YRS. EXPOSURE

HEARING THRESHOLDS OF A NON-NOISE-EXPOSED POPULATION IN DUNDEE

W. TAYLOR, J. PEARSON AND, A. MAIR

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Hearing Thresholds of a Non-noise-exposed Population in Dundee

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In order to provide a control population for a previous investigation of noise-induced hearing loss in a population of female jute weavers (Taylor, Pearson, Mair, and Burns, 1965) a survey was conducted on the hearing thresholds of 296 school teachers in Dundee, Scotland, by pure tone earphone listening. This population, although not exposed to industrial noise, is subjected to city noise and differs, therefore, from the rural population of Hinchcliffe (1959), whose presbycusis data have been used in previous studies.

The results show that Dundee female school teachers do not conform to British Standard in the age group 18-24 years. The presbycusis data (18-65 years age group), however, show close agreement with those of Hinchcliffe (1959) and Corso (1963). The distributions of hearing threshold observed were normal.

In the assessment of hearing loss due to loom noise in a population of Dundee female jute weavers (Taylor *et al.*, 1965) it was necessary to estimate hearing threshold changes due to advancing years (presbycusis). This was done using the results available in the work of Hinchcliffe (1959) on a rural population in Scotland.

It may be argued, however, that a rural population is not exposed to noise levels similar to those found within the City of Dundee and its suburbs, and that such a population may not be used as a control for the Dundee weavers.

It was, therefore, necessary to find a predominantly female population not exposed to industrial noise and yet living in Dundee. Moreover, it was desirable to choose, as the control population, a large, stable occupational group with a single central administration. No industrial group satisfied these conditions. The population of female school teachers employed by the Local Authority was found to be suitable for this investigation.

Consequently, a survey has been conducted on Dundee school teachers resident in the city and its surrounding residential area to obtain control data for the threshold of hearing levels in jute weavers.

An integral part of the survey was the investigation of the effect of age on hearing in a city, compared with the findings already published for a rural population (Hinchcliffe, 1959).

Received for publication August 25, 1966.

Method

Measurement of Hearing Level Pure-tone air conduction audiometry, performed according to the method recommended by Littler (1962), was used at frequencies of 125, 250, 500, 1,000, 2,000, 3,000, 4,000, 6,000, and 8,000 c.p.s. in 2·5 dB steps. Throughout the survey, a Peters clinical audiometer type SPD/2 with TDH-39 telephones and MX41/AR cushions, adjusted to conform to British Standard Specification 2497 (1954), was used. All audiometric measurements were made by one of us (W.T.), alternating right and left earphones and using the same test procedure on each subject.

Calibration of Audiometer The calibration of the audiometer was carried out at six-monthly intervals by an independent laboratory with the tolerances specified in British Standard Specification 2980 (1958). Weekly checks for drift were made by means of an artificial ear. In addition, the electrical output of the oscillator of the audiometer was monitored for voltage and frequency before each individual audiometric test. Throughout the period of this study, the electrical output of the audiometer showed no significant variation. However, changes (which may have introduced unknown variations of not more than 1·5 dB relative to British Standard) did occur in the telephones over six-monthly periods.

Audiometric Environment A constant audiometric test environment was provided by means of an audiometric booth mounted inside a sound-insulated trailer (Taylor, Burns, and Mair, 1964), the attenuation of booth and vehicle shell being such that measurement of hearing was possible to -10 dB at all test frequencies while the vehicle was parked close to schools. Care was taken to avoid areas adjacent to music classrooms, and testing was suspended at school intervals, due to marked increases in ambient noise levels.

Selection of Subjects The teachers examined were employed by the Local Authority. With the permission of the Dundee Education Committee, the headmasters of 15 randomly chosen schools in the city were contacted. The teachers themselves were then approached. The staff at one school (18 teachers) refused to join the study following an unfounded rumour that the medical information was not confidential. In each of the remaining 14 schools, the response was above 95%.

Procedure All subjects were first interviewed to elicit a complete history relevant to hearing. Medical facts, past or present noise exposure, and time spent in the teaching profession were ascertained. In the medical history, particular attention was paid to concussive head injuries and the administration of drugs liable to affect hearing. Then followed a clinical otological examination which included the normal procedure of examination of the tympanic membrane and pharynx. If wax was present in the external meatus in any quantity, this was noted. The order in which audiometric examinations were performed was random and unrelated to teaching experience.

Criteria for Normal Subjects A subject was considered to be normal if (1) both ear drums appeared normal; (2) no history of aural disease, past or present, was given; (3) neither ear drum was obscured by wax; (4) no upper respiratory tract infection was present at the time of the test; and (5) no history of exposure to excessive noise was given (industrial noise, shooting, explosives, etc.).

Noise Levels It was not the purpose of this study to conduct noise surveys in schools. Nevertheless, certain information came to light in the questionnaires which suggested that noise levels in some classrooms might be excessive, and indeed above the range at which damage to hearing might occur. One large modern school was selected and a noise survey undertaken, using a Bruel and Kjaer sound level meter type 2203 and an octave band analyser type 1613.

TABLE I

SUMMARY OF SOUND PRESSURE LEVELS IN ONE SCHOOL

Classroom	*Range of Values Observed (dBA)*
Music	80–87
Sports	75–85
Technical	87–92
Other	55–70

TABLE II

TOTAL TEACHER POPULATION EXAMINED

Teacher Group	*Male*	*Female*	*Total*
Special groups			
Technical	13	—	13
Physical training	4	4	8
Music	4	2	6
With possible occupational noise exposure	21	6	27
With no occupational noise exposure	66	203	269
Grand Total	87	209	296

Results and Discussion

In all, 296 teachers (209 women, 87 men) were examined in the survey.

The ranges of noise levels obtained in the different types of class-room are shown in Table I, using the 'A' weighted loudness scale. For the purposes of this study, a group of teachers subjected to a uniform, low level of noise was required. To produce this homogeneous group it was necessary to exclude from the analysis the audiograms of 13 teachers of technical subjects, eight physical training instructors, and six music teachers, these being the subjects associated with the higher sound pressure levels (Tables I and II).

Numbers were further reduced when the selection criteria for normal hearing were applied. In all, 18 (27%) of the men and 32 (16%) of the women were rejected, for reasons shown in Table III. The numbers rejected included 18 persons (6·7%) excluded because of abnormalities in one ear. The second ear of these persons was not used in the survey.

The remaining 219 teachers (171 women, 48 men) were grouped into six age-groups as shown in Table IV. It was not considered profitable to analyse the audiograms of the men at this time, due to insufficient numbers, and so it was decided to limit the study to the original objective of assessing the hearing level of women teachers, in order to provide a control group for a hearing level study of Dundee weavers, all of whom were women. In an effort to increase the accuracy, the observed mean age of each group was calculated (Table IV). This value, and not the mid-point of the age-group, was used in plotting the presbycusis curves. The first analyses concentrated on the 18-24 years age group. The mean hearing level was calculated (Table V, Fig. 1) to demonstrate the audiometric zero dB

TABLE III

POPULATION SELECTED FOR STUDY

Decision	Male		Female		Total	
	No.	%	No.	%	No.	%
Not accepted for study due to:						
Ear pathology	7	10·6	19	9·4	26	9·7
Wax	2	3·0	4	2·0	6	2·2
Upper respiratory tract infection	—	—	6	3·0	6	2·2
Pre-test history of ear disease	1	1·5	—	—	1	0·4
Extraneous noise	8	12·1	1	0·5	9	3·3
Less than 18 years of age	—	—	1	0·5	1	0·4
Insufficient information	—	—	1	0·5	1	0·4
Total not accepted	18	27·3	32	15·8	50	18·6
Accepted for study	48	72·7	171	84·2	219	81·4
Total	66	100·0	203	100·0	269	100·0

TABLE IV

AGE ANALYSIS OF POPULATION ACCEPTED FOR STUDY

Age Group (yrs.)	Male		Female		Total
	No.	Mean Age	No.	Mean Age	
18–24	7	23·3	46	22·3	53
25–34	12	29·5	33	28·4	45
35–44	10	39·3	29	39·3	39
45–54	12	49·4	35	50·3	47
55–64	6	60·3	26	58·0	32
65–74	1	67·0	2	65·0	3
Total	48	—	171	—	219

average for this age group. It was evident that the mean hearing level of young teachers did not conform to the British Standard zero dB, being better by 3·7 dB at 1 kc/s. This could have occurred due to chance variation, and, to investigate this possibility, the 95% confidence region shown in Fig. 1 was constructed. This region represents the probable location of the mean hearing level of the population from which our sample was drawn. The major part of the zero dB line lies outside this region and it is therefore unlikely that the observed difference is due to chance. The discrepancy may have been due to calibration errors. However, the routine checks showed no consistent trends and it is probable that no overall calibration effect resulted from the small random changes observed. It was, therefore, concluded that the hearing of women teachers, at least in Dundee, differed from that of the British Standard. This finding was further supported by the small standard deviations (Table VI). The variation (measured by the standard deviation) observed in the group of teachers was significantly less ($p < 0·01$) than that reported for laboratory workers by Dadson and King (1952).

In the investigation of the hearing levels of weavers (Taylor *et al.*, 1965) the distribution of hearing was discussed. This important statistical aspect of the hearing threshold problem was again considered in this study. Table VII and Fig. 2 show the distribution of hearing level for the 18-24 years age group at all frequencies. The distributions obtained are symmetrical and it was found that they could be reasonably approximated by a normal distribution. This is illustrated for 4 kc/s in Fig. 3 and Table VIII.

When dealing with distributions not significantly different from the normal distribution, statistical theory states that the most precise, most efficient

TABLE V

Mean Threshold at 95% Confidence Limits for the Mean for 46 Female Teachers (92 ears) aged 18-24 Years

Level (dB)	*Audiometric Frequency (kc/s)*								
	0·125	0·25	0·5	1	2	3	4	6	8
Lower limit (dB)	−0·14	−2·15	−3.42	−5·04	−3·11	−2·31	−4·24	−2·08	−1·59
Mean level (dB)	1·63	−0·54	−1·96	−3·70	−2·04	−2·17	−2·65	−0·46	0·00
Upper limit (dB)	3·40	1·07	−0·50	−2·36	−1·03	−0·77	−1·06	1·16	1·59

TABLE VI

Mean and Standard Deviation (dB) for each Age Group and Frequency

cy	*Ear*	*Age Group (yrs)*														
		18–24			25–34			35–44			45–54			55–64		
		No. of Ears	*Mean (dB)*	*S.D.*	*No. of Ears*	*Mean (dB)*	*S.D.*	*No. of Ears*	*Mean (dB)*	*S.D.*	*No. of Ears*	*Mean (dB)*	*S.D.*	*No. of. Ears*	*Mean (dB)*	*S.D.*
	Right	46	2·66	4·52	33	2·31	4·15	29	4·27	4·60	35	6·25	7·23	26	5·29	3·88
	Left	46	0·60	4·49	33	0·80	5·32	29	2·80	3·23	35	2·89	5·78	26	4·13	4·45
	Both[1]	92	1·63	4·60	66	1·55	4·79	58	3·53	4·01	70	4·57	6·71	52	4·71	4·18
	Right	46	0·05	4·17	33	0·57	3·82	29	0·99	3·68	35	3·32	5·99	26	3·94	3·23
	Left	46	−1·14	4·01	33	0·04	4·81	29	0·22	3·38	35	2·11	5·72	26	1·92	4·33
	Both	92	−0·54	4·12	66	0·30	4·31	58	0·60	3·52	70	2·71	5·84	52	2·93	3·92
	Right	46	−0·98	4·12	33	0·34	3·30	29	0·65	2·81	35	2·82	5·49	26	3·37	2·89
	Left	46	−2·93	3·34	32	−1·17	4·38	29	−0·65	3·64	35	1·75	4·24	26	2·60	4·20
	Both	92	−1·96	3·86	65	−0·40	3·91	58	0·00	3·29	70	2·29	4·90	52	2·98	3·59
	Right	46	−3·37	3·65	33	−1·86	4·05	29	−2·11	3·22	35	1·68	4·94	26	0·77	4·06
	Left	46	−4·02	3·26	32	−2·89	3·51	29	−2·11	3·36	35	−0·18	4·75	26	1·15	4·03
	Both	92	−3·70	3·46	65	−2·37	3·80	58	−2·11	3·26	70	0·75	4·90	52	0·96	4·01
	Right	46	−1·90	3·14	33	0·19	4·33	29	0·13	3·10	35	2·61	6·01	26	3·85	5·22
	Left	46	−2·17	3·39	32	−1·56	4·52	29	1·08	5·47	35	3·61	6·70	26	4·04	6·87
	Both	92	−2·04	3·25	65	−0·67	4·48	58	0·60	4·43	70	3·11	6·34	52	3·94	6·04
	Right	46	−2·01	3·49	33	−0·95	3·74	29	1·08	3·40	35	4·04	6·85	26	5·38	5·83
	Left	46	−2·34	3·75	32	−2·03	3·94	29	1·77	5·40	35	6·61	7·18	26	7·40	7·72
	Both	92	−2·17	3·61	65	−1·48	3·85	58	1·42	4·49	70	5·32	7·09	52	6·39	6·85
	Right	46	−2·75	3·91	33	−1·10	4·84	29	2·37	5·11	35	5·61	6·92	26	9·04	9·44
	Left	46	−2·55	4·27	32	−1·88	3·81	29	4·01	8·97	35	9·96	9·06	26	11·25	9·14
	Both	92	−2·65	4·07	65	−1·48	4·35	58	3·19	7·29	70	7·79	8·30	52	10·14	9·27
	Right	46	0·22	4·43	33	1·25	5·38	29	6·16	6·49	35	14·46	11·80	26	19·90	11·67
	Left	46	−1·14	4·94	33	0·27	4·19	29	8·04	6·63	35	17·81	12·80	26	20·10	12·47
	Both	92	−0·46	4·72	66	0·76	4·81	58	7·10	6·57	70	16·14	12·33	52	20·00	11·96
	Right	46	0·76	4·37	33	1·92	4·61	29	9·27	7·54	35	19·39	13·64	26	25·38	14·09
	Left	46	−0·76	4·73	33	1·10	5·52	29	9·01	6·66	35	21·88	17·21	26	26·15	12·85
	Both	92	0·00	4·59	66	1·51	5·06	58	9·14	7·05	70	20·64	15·47	52	25·77	13·36

—considering the observations as coming from individual ears

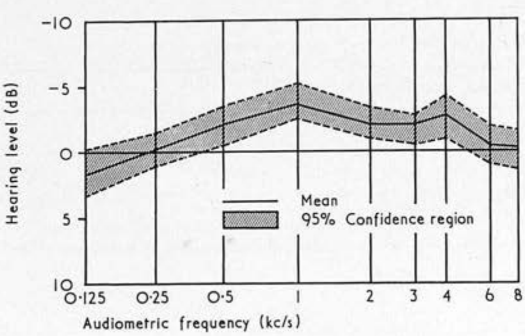

FIG. 1. Ninety-five per cent. confidence region for mean audiogram of 46 female teachers (92 ears) aged 18-24 years.

average value is the mean of the sample and not the median. Since the distributions observed in this study fall into this category, all analyses have been in terms of means.

In Fig. 3 the distribution of hearing level is shown separately for right and left ears. The same normal curve was satisfactorily fitted to both distributions, indicating that no significant difference exists between the mean hearing levels of the right and left ears.

In assessing noise-induced hearing loss the critical audiometric frequency is 4 kc/s. It is, therefore, important to have maximum information on the effect of age at this frequency. The distribution of hearing level in each age group is shown in Table IX and Figure 4. The mean hearing level and the variability of the level increase with increasing age, and in the later age groups some tendency towards

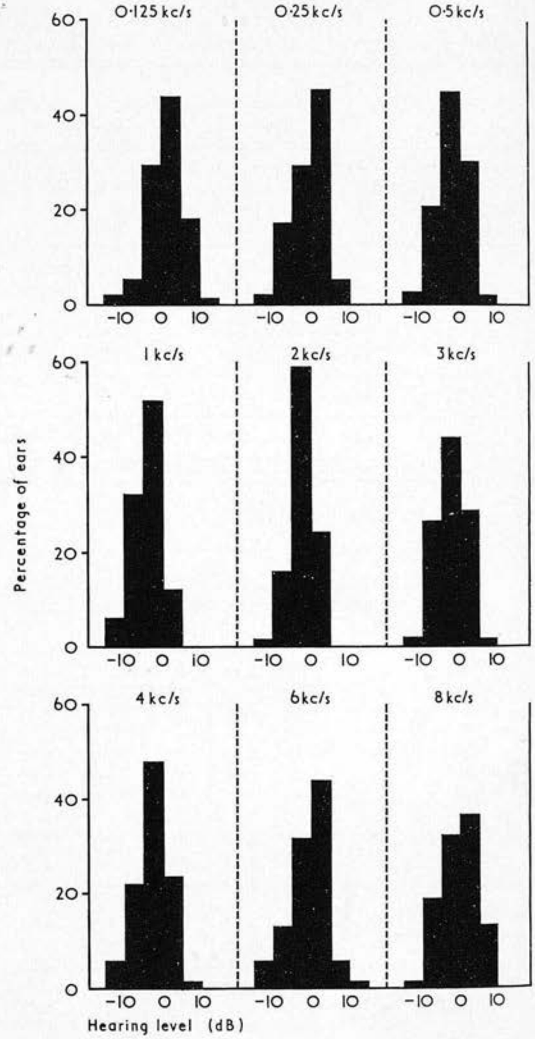

FIG. 2. (Right) Distribution of hearing level of 46 female teachers (92 ears) aged 18-24 years.

TABLE VII

DISTRIBUTION OF HEARING LEVEL OF 46 FEMALE TEACHERS (92 EARS) AGED 18–24 YEARS

dB	*Audiometric Frequency (kc/s)*								
	0·125	0·25	0·5	1	2	3	4	6	8
−10	2	2	2	5	1	1	5	5	1
−5	5	16	19	29	15	24	20	12	17
0	27	27	41	47	54	40	44	29	29
5	40	42	28	11	22	26	22	40	33
10	17	5	2	0	0	1	1	5	12
15	1	0	0	0	0	0	0	1	0
Total	92	92	92	92	92	92	92	92	92

TABLE VIII

DISTRIBUTION OF HEARING LEVEL AT 4 KC/S OF 46 FEMALE TEACHERS (92 EARS) AGED 18–24 YEARS

dB	*Ear*		
	Right	*Left*	*Both*
−10	2	3	5
−5	12	8	20
0	20	24	44
5	12	10	22
10	0	1	1
Total	46	46	92

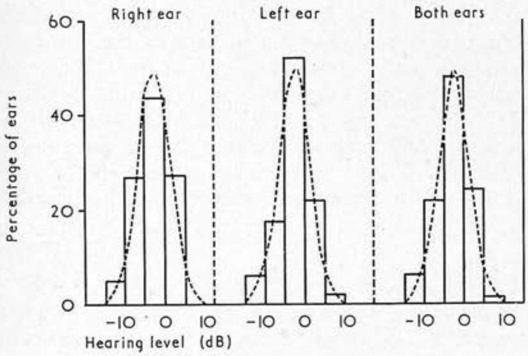

FIG. 3. Distribution of hearing level at 4 kc/s of 46 female teachers (92 ears) aged 18-24 years.

TABLE IX

DISTRIBUTION OF HEARING LEVEL AT 4 KC/S OF FEMALE TEACHERS IN DIFFERENT AGE GROUPS

dB	*Age (yrs)*				
	18–24	25–34	35–44	45–54	55–64
−10	5	2	0	0	0
−5	20	14	5	1	1
0	44	25	17	12	5
5	22	20	16	17	11
10	1	4	11	16	15
15	0	0	8	13	6
20	0	0	0	5	9
25	0	0	0	3	1
30	0	0	0	1	2
35	0	0	0	2	0
40	0	0	1	0	2
Total	92	65	58	70	52

skewness is suggested. The theoretical normal distribution was again fitted and it was found to give a sufficiently close approximation for reasonable confidence to be placed in the use of statistical tests requiring normality. The approximately normal distributions again emphasize the desirability of using the mean as the average value.

When these analyses were extended to the other age groups and audiometric frequencies, similar results were obtained.

Presbycusis This investigation was undertaken with a view to measuring the threshold shift due to age in a non-noise-exposed population. The exact determination of the presbycusis effect is manifestly impossible since serial audiograms for each patient throughout life are not available. True threshold shift cannot therefore be measured. In order to estimate the hearing loss due to age, it was assumed that the audiogram of the 18-24 years age group represents the hearing of the other age groups in earlier years. Therefore, mean hearing loss from the age of 21·5 years was estimated as the difference

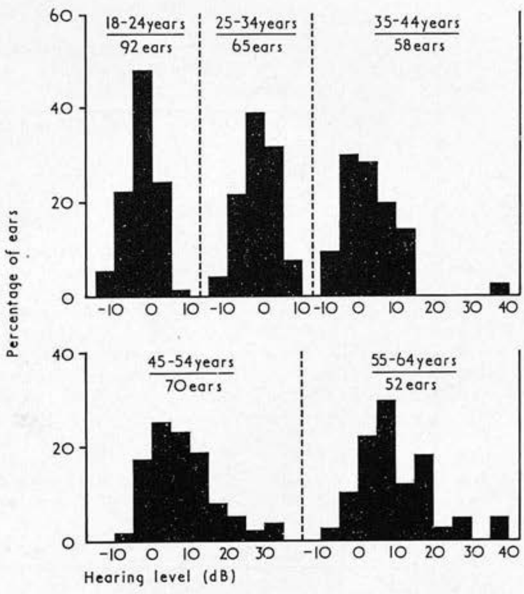

FIG. 4. Distribution of hearing level at 4 kc/s of female teachers of different ages.

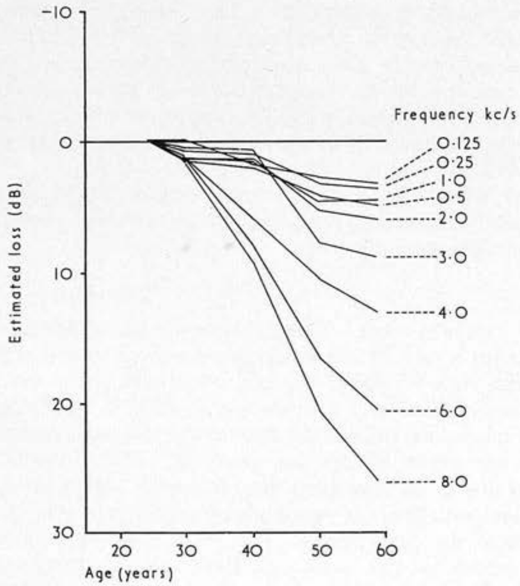

FIG. 5. Estimated loss of hearing as a function of age in female school teachers.

between the observed mean at each age and that of the 18-24 years age group. Figure 5 shows the resulting estimates in the form of presbycusis curves. The estimated loss increases with age and with frequency. At 4 kc/s the observed mean loss was 13 dB at 60 years. The estimated loss in the frequencies important for speech is not severe, the mean for the frequencies 0·5, 1 and, 2 kc/s being 5·2 dB at 60 years of age. For the mean of the four frequencies, 0·5, 1, 2, and 3 kc/s, at 60 years of age the figure is 6·3 dB.

Finally, a comparison was made between the schoolteacher population and two other populations which have been surveyed by Hinchcliffe (1959) and Corso (1963) respectively (Fig. 6). In making any comparison of statistical averages based on samples, these estimates are subject to variability. In order to allow for this uncertainty, a region was again constructed which defined the probable location of the presbycusis curves for the Dundee schoolteachers (Table X). At this point it should be noted that high positive correlation was observed in this study between the two ears of the subjects (Table XI). This leads to an increase in the variability of the mean and a corresponding increase

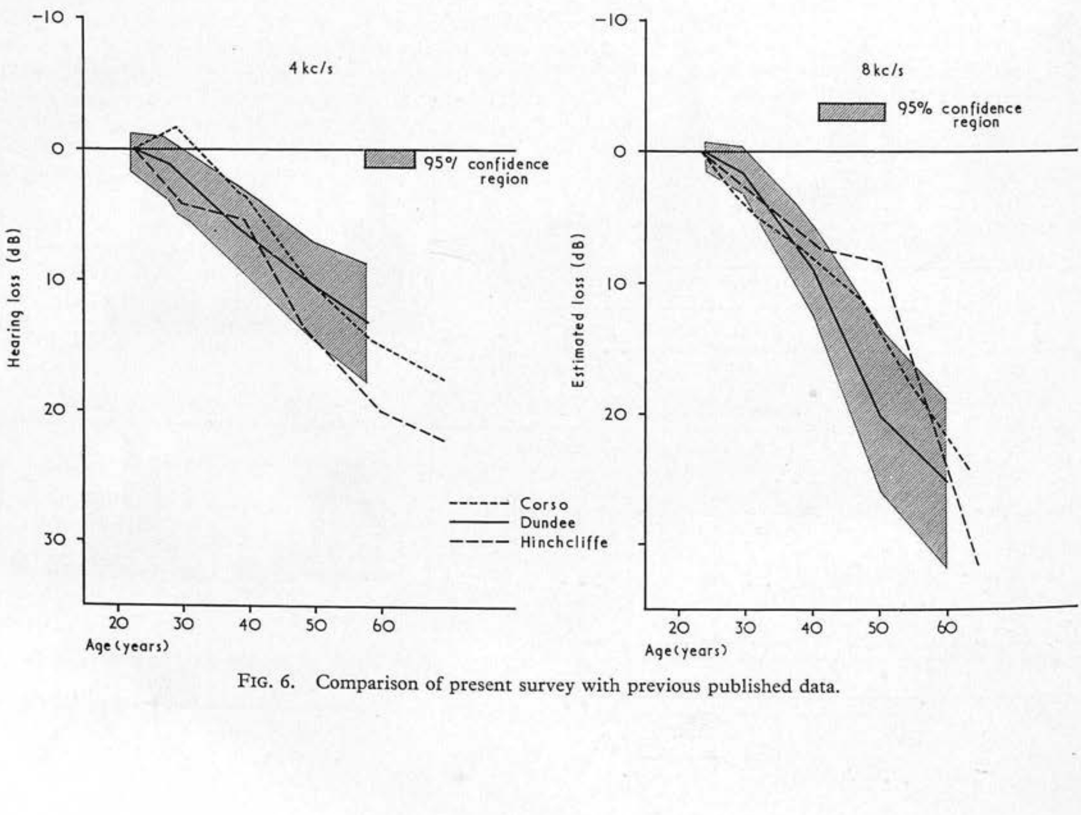

FIG. 6. Comparison of present survey with previous published data.

TABLE X

95% Confidence Limits for Mean Estimated Presbycusis Loss at 4 kc/s and 8 kc/s for Different Ages

dB	*4 kc/s*			*8 kc/s*		
	Lower Limit	*Mean*	*Upper Limit*	*Lower Limit*	*Mean*	*Upper Limit*
18–24	−1·40	0	1·40	−1.44	0	1·44
25–34	−1·12	1·17	3·46	−0·82	1·51	3·84
35–44	2·39	5·84	9·29	5·65	9·14	12·63
45–54	6·77	10·44	14·11	13·80	20·37	26·94
55–64	8·02	12·80	17·58	19·28	25·77	32·26

in the area of the confidence regions. The correlation effect has been included in all regions constructed for this study. The curves estimated by Hinchcliffe and Corso lie almost entirely within the region of variability. When the sampling variability of these estimates is also considered, it is likely that a conclusion of no difference would result. Thus, the survey of schoolteachers in Dundee has revealed ageing effects similar to those recorded elsewhere.

Conclusions

The variability observed in the hearing levels of Dundee schoolteachers was smaller than that in the population used to establish the British Standard.

The mean hearing level of the 18-24 years age group differed significantly from the British Standard of normal hearing.

The distributions of hearing level observed were approximately normal.

The mean and variability (measured by standard deviation) of hearing level increased with age.

No statistically significant (5% level of significance) difference was observed between right and left ears, and positive correlations which could not be neglected were observed between ears.

Ninety-five per cent. confidence intervals for hearing loss due to age between 21·5 and 60 years were estimated to be 13 ± 5 dB at 4 kc/s, and 25 ± 6 dB at 8 kc/s. The mean loss between 21·5 and 60 years at the three frequencies, 0·5, 1, and 2 kc/s, was 5·2 dB. The mean loss at the four frequencies, 0·5, 1, 2, and 3 kc/s, was 6·3 dB.

At 4 kc/s and 8 kc/s no major differences were discovered between the estimates of presbycusis obtained in this study and those of Hinchcliffe (1959) and Corso (1963).

The mobile audiometric unit, audiometer, and noise instrumentation were provided by a grant from the Advisory Committee for Medical Research in Scotland. We are indebted to Dr. J. M. A. Lenihan and Miss E. C. Knox of the Physics Department, Western Regional Hospital Board, Glasgow for calibration of the audiometers; to Mrs. A. Henderson and Mrs. W. M. Massie for technical assistance; and to Mr. J. Carson, Director of Education, and the Dundee Education Authority for their co-operation in this study.

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TABLE XI

Correlation of Hearing Level Between Right and Left Ears for Each Age Group and Frequency

Frequency (kc/s)	*Age Group (yrs.)* 18–24		25–34		35–44		45–54		55–64	
	No. of Persons	*Correlation Coefficient*	*No. of Persons*	*Correlation Coefficient*	*No. of Persons*	*Correlation Coefficient*	*No. of Persons*	*Correlation Coefficient*	*No. of Persons*	*Correlation Coefficient*
0·125	46	0·71	33	0·75	29	0·57	35	0·56	26	0·66
0·25	46	0·72	33	0·72	29	0·62	35	0·38	26	0·65
0·5	46	0·68	32	0·69	29	0·58	35	0·64	26	0·58
1·0	46	0·65	32	0·55	29	0·63	35	0·67	26	0·72
2·0	46	0·19	32	0·54	29	0·57	35	0·71	26	0·79
3·0	46	0·65	32	0·58	29	0·53	35	0·76	26	0·80
4·0	46	0·67	32	0·68	29	0·60	35	0·73	26	0·87
6·0	46	0·32	33	0·41	29	0·52	35	0·67	26	0·66
8·0	46	0·35	33	0·29	29	0·75	35	0·78	26	0·73

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APPENDIX

Approximate Standard Deviation with Correlation between Ears

The usual standard deviation of the mean (standard error) is given by $\sigma/\sqrt{N}$ where σ is the standard deviation of the population and N is the number of observations. In the case of hearing loss, the observations occur in correlated pairs, violating the assumption of independence implicit in the above formula.

Assuming a common mean μ and standard deviation σ for right and left ears and a correlation ρ between ears of a subject, the standard deviation of the mean becomes

$$\sqrt{\frac{\sigma^2(1 + \rho)}{2n}},$$

where pairs of observations are taken on n subjects.

The standard deviation is estimated by:

$$\sqrt{\frac{s^2(1 + r)}{2n}},$$

where s is the best estimate of σ and r the estimate of ρ. The inclusion of the correlation effect causes an increase of approximately 34% if $r = 0{\cdot}8$ and of 27% if $r = 0{\cdot}6$.

Approximate 95% Confidence Limits for 'Curves'

Although drawn as curves, the estimates of presbycusis and mean audiograms are, in fact, simply a series of points. The 'curves' estimating the 'confidence region' are similarly constructed and the result is a collection of simultaneous confidence intervals, correct only at the ages or frequencies of construction and providing, at best, crude estimates between these points.

Confidence limits are constructed at each point used to draw the 'curve', such that the overall confidence is 95%, *i.e.*, such that the probability that the true mean falls outside the region constructed is 0·05.

The limits at the individual points are constructed with corresponding probability P, given by:

$$P = 1 - \text{antilog}\left\{\frac{\log 0.95}{a}\right\}$$

where 'curve' consists of a points.

For large samples a normal approximation is assumed and the confidence limit at each point is:

$$\text{mean} \pm N_P \times (\text{standard deviation of mean}),$$

where N_P is the normal deviate excluding a proportion $P/2$ of observations in each tail of the distribution.

For example, if five points are used for the curve:

$$P = 1 - \text{antilog}\left\{\frac{\log 0{\cdot}95}{5}\right\}$$

$$= 0{\cdot}0103$$

From tables of the normal probability integral

$$N_P = 2{\cdot}57$$

Thus, for an overall confidence of 95% the individual confidence limit should be set at approximately 99% when five points have been used.

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Study of Noise and Hearing in Jute Weaving

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A retrospective study of hearing in a female population exposed to weaving noise is described. The noise is believed to have remained substantially unaltered over periods of exposure ranging from less than 1–52 years. The deterioration of hearing due to noise has been assumed to be estimated by the difference between the recorded hearing level and the expected hearing level from other published presybcusis data. Patterns of deterioration of hearing are described for various audiometric frequencies. The most conspicuous feature is an initial deterioration in the first 10–15 years of exposure, followed by a period of about 10 years where deterioration attributable to noise is small. Thereafter, after 20–25 years of exposure, further deterioration occurs, especially marked at 2000 cps. The possible distribution of noise-induced threshold changes is briefly considered.

INTRODUCTION

IN the city of Dundee, Scotland, between 3000 and 4000 persons are occupationally exposed to the noise of jute-weaving machinery. A restrospective study of the relation between noise exposure and hearing in a section of this population is described here.

For the purpose of this investigation, a population working in two particular weaving areas was selected for the following reasons. The noise of the looms in one of the two weaving areas used is likely to have been constant since the looms were installed in 1892. A change from belt drive to independent electric drive was made in 1945 but, from observations of belt and shafting noise and of motor-drive noise, it does not appear that a significant change in the noise is likely to have occurred as a result of this change. In the other weaving area used in this investigation, the noise was virtually the same (the looms being identical) and again it seems unlikely that the noise has altered significantly over more than 50 years, since the only change has been a gradual one from belt to motor drive during the years 1950–1954. In addition, the weaving population is predominantly female, and not subjected to other types of high-intensity noise. This population is a stable one, with remarkably long service, in some cases up to 50 years in the same weaving shed and even at the same loom. In view of the fact that the effect of age on the hearing of women is less obscured by the effects of incidental noise exposure than in men, a female population is preferable if age has to be taken into account in assessing hearing. In addition, there was available a small number of retired weavers, with a known history of exposure to weaving noise.

The general procedure in this study is similar to previous retrospective investigations.[1] After eliminating as far as possible those subjects who might have sustained a hearing loss from a reason other than weaving noise or age, a quantitative estimate is made, after allowing for the effects of age (presbycusis), of the hearing loss associated with known periods of exposure to the weaving noise.

I. METHODS

A. Measurement of Noise

The noise in 14 jute mills in Dundee and district was surveyed using Brüel & Kjær equipment. Over-all sound-pressure levels (SPL *re* 0.0002 μbar) were meas-

[1] ASA Exploratory Subcommittee *Z-24-X-2, The Relations of Hearing Loss to Noise Exposure* (American Standards Association, New York, 1954).

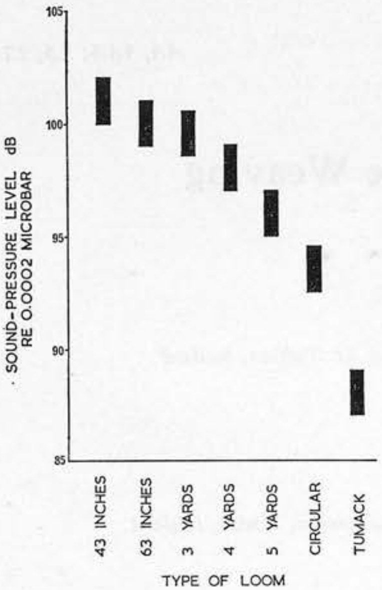

FIG. 1. Range of SPL values in weaving areas with different loom types.

ured for various processes of manufacture and loom types (sound-level meter B & K type 2203). In addition, narrow-band (selectivity 6% at 3 dB bandwidth) and octave analyses were performed (analyzer B & K types 2107 and 1613, respectively) in the loom passes and at weavers' rest seats in the narrow-loom (43 and 63 in.) section, which was chosen for the investigation.

B. Measurement of Hearing

Pure-tone air-conduction audiometry, as recommended by Littler,[2] was used at frequencies of 125, 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 cps in 2.5-dB steps. A Peters clinical audiometer type SPD/2 was used, with TDH-39 telephones and MX 41/AR cushions, adjusted to conform to the British standard[3] for the normal threshold of hearing.

C. Audiometer Calibration

This work originated as a fairly urgent clinical assessment of the incidence of occupational hearing loss in this industry, and initially facilities were not available for the daily calibration of the audiometric equipment. For these and other reasons, the audiometer was calibrated by an independent laboratory with the tolerances specified in British Standard 2980 (Ref. 4); the majority of the measurements were made within 3 months of calibrations. In addition, the electrical output of the oscillator of the audiometer (but not the output stages) was monitored and, if necessary, adjusted for voltage and frequency before audiometry of each individual subject; and, on each day on which weavers were examined, audiograms were performed on the same group of normal subjects, numbering 3–5, as a check for gross malfunction of the output stages or telephones. Throughout the period of this study, the electrical output of the audiometer showed no significant change; some changes occurred in the telephones. It has been possible to assess with reasonable confidence the effects of these departures from the British standard[3] audiometric zero values.

The calibrations indicate that, for the weaver population, the audiometer is likely to have introduced an error of about -1.5 dB relative to the British standard,[3] in the median values of hearing level, while the variation between the values for individual frequencies is likely to be of the order of ± 1 dB, for all frequencies other than 6000 and 8000 cps. For these, the acoustic output, on the average, was too low by 3 ± 1 dB, and the data on weavers have been corrected so that 6000 and 8000 cps have the same small error as have the other frequencies.

The raw data on the populations not exposed to noise (groups I and II) contained probable mean errors of less than $+1\pm 1$ dB for all frequencies except 6000 and 8000 cps, for which the estimated error was $+3\pm 0.5$ dB. All audiometric data in these categories have been corrected so as to be relative to the British standard.[3] The variations in the audiometric acoustic output for the weavers, while combining to give the mean value stated above, have probably increased the range of values by 1 step of 5 dB or not more than 3 steps of 2.5 dB.

D. Audiometric Environment

The first audiograms were obtained in a commercially available audiometric test room located in a quiet site in an office area. Subsequently, this test room was incorporated into a mobile audiometric unit in the form of a trailer.[5] By this means, in the normal ambient noise in the vicinity of jute-mill buildings, hearing levels of -10 dB could be measured without error due to masking at all frequencies except 125 cps, at which -5 dB hearing level, referred to the British standard[3] was similarly measurable.

E. Hearing Survey

1. Groups of Subjects

All subjects were female and were grouped as follows:

Group I: Employees in the jute industry not exposed to noise and aged 18–25 years

Group II: School teachers aged 18–25 years

These two groups were controls, mainly to verify that young subjects, ostensibly not exposed to noise,

[2] T. S. Littler, "Techniques of Industrial Audiometry," Natl. Phys. Lab. Gt. Brit. Proc. Symp. 12, 285–293 (1962).

[3] British Standard 2497: 1954, *The Normal Threshold of Hearing for Pure Tones by Earphone Listening* (British Standards Institution, London, 1954).

[4] British Standard 2980: 1958, *Pure-Tone Audiometers* (British Standards Institution, London, 1958).

[5] W. Taylor, W. Burns, and A. Mair, "A Mobile Unit for the Assessment of Hearing," Ann. Occup. Hyg. 7, No. 4, 343–351 (1964).

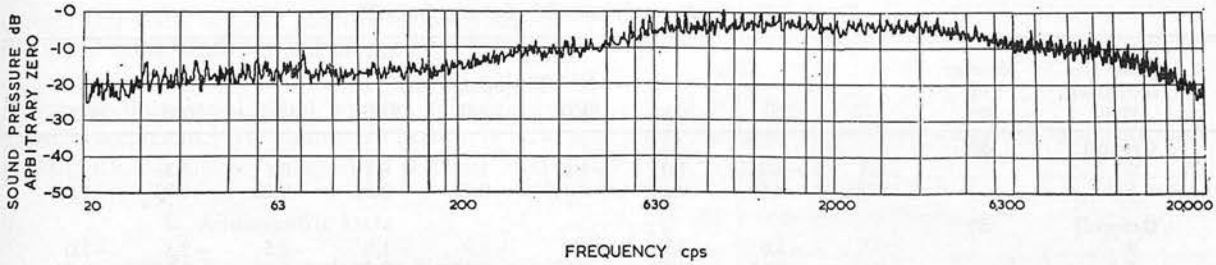

FIG. 2. Noise in areas occupied by 43- and 63-in. looms. Narrow-band analysis. Selectivity at 3-dB bandwidth is 6%.

gave hearing thresholds comparable to those of the British standard.[3]

Group III: Employed weavers, with various durations of exposure to the known weaving noise

Group IV: Retired weavers, with various durations of exposure to the known weaving noise, followed by various durations of retirement

2. *Selection of Subjects*

All subjects were volunteers. Despite the disadvantages of this form of selection there was virtually no alternative in this survey. The response in group I was difficult to assess numerically, but in groups II–IV it was high; in group III, the response was 100% of the weavers in the two selected areas, and, in group IV, in the region of 90%.

3. *Procedure*

All subjects were interviewed and given a clinical otological examination before audiometry. The former consisted of a questionnaire designed to elict a medical history relevant to hearing and to define the previous noise exposure. The clinical otological examination included the normal procedure of examination of the tympanic membrane, pharynx, and, if a conductive hearing loss was suspected, Rinne and Weber tests. If earwax was present in sufficient quantity to obscure the membrane, it was removed, and audiometry performed one week later. In the present survey, all volunteers were examined audiometrically, but their inclusion in the data depended on the fulfillment of certain conditions. These were that there should be (1) no evidence of past or present aural disease or abnormality; (2) no history of exposure either to noise (groups I and II) or to noise other than the specific weaving noise (groups III and IV); (3) no medical history suggestive of abnormality of hearing—for example, concussive head injury or the administration of drugs liable to affect hearing.

All audiometry was conducted on Monday mornings in the case of group III, so that not less than approximately 63 h had elapsed since the last noise exposure for day workers and periods of approximately 56–72 h in the case of shift workers. A total of 6 weavers had longer intervals than this, in the region of 2 weeks, since the last noise exposure at work. The order in which audiometric examinations were performed was random and unrelated to age or to duration of exposure to noise.

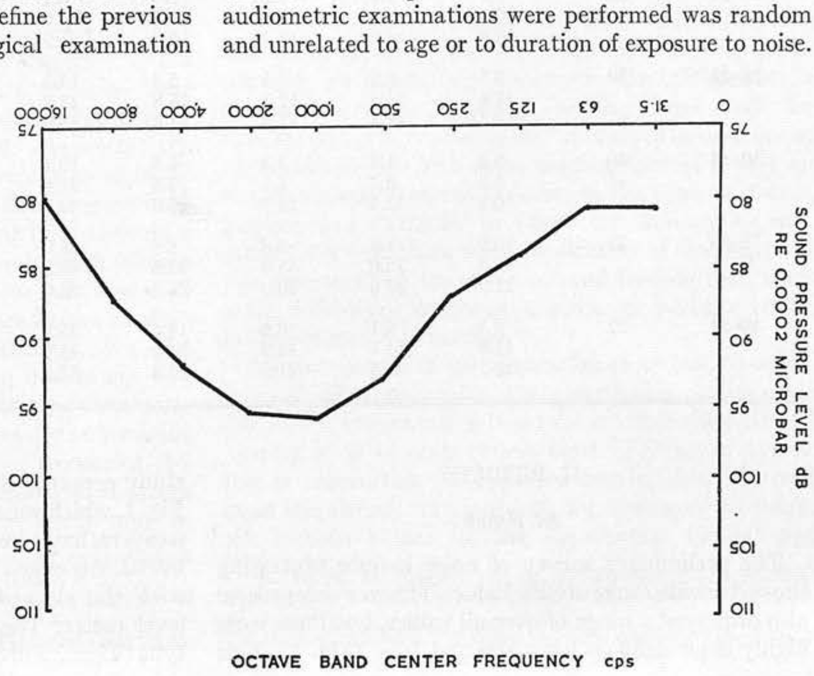

FIG. 3. Noise in areas occupied by 43- and 63-in. looms. Octave-band analysis.

TABLE I. Hearing levels (mean, dB) of groups I and II.

Group and statistical value	Number of ears	Frequency (cps) 125	250	500	1000	2000	3000	4000	6000	8000
Group I	58									
$\bar{x}$		4.4	0.0	1.0	−1.6	1.1	0.1	−0.7	2.8	2.7
S.E.		0.50	0.44	0.43	0.50	0.52	0.51	0.62	0.83	1.02
Group II	50									
$\bar{x}$		0.8	−2.0	−2.3	−4.9	−0.9	−1.8	−2.5	−2.3	−1.0
S.E.		0.48	0.42	0.42	0.17	0.34	0.38	0.54	0.75	0.83

TABLE II. Estimated noise-induced threshold shift (expressed as 25th percentile, median, and 75th percentile in dB) of group III, classified by exposure duration.

Noise exposure completed years	Number of ears	Frequency (cps) 125	250	500	1000	2000	3000	4000	6000	8000
<1	43	−1.5	−0.7	−0.3	−1.6	−1.5	−1.4	3.0	−0.6	−4.7
		1.0	1.8	2.5	0.0	1.7	0.5	6.3	4.6	−0.3
		4.5	4.2	4.6	3.8	3.8	4.4	14.2	13.0	4.9
1–2	50	−1.5	−1.5	−1.2	−2.1	−1.6	1.5	4.7	4.1	−1.0
		0.8	−0.3	0.3	−1.0	−0.3	4.3	14.8	10.3	5.0
		4.4	3.0	2.1	0.3	2.8	12.6	25.6	20.2	12.1
3–4	42	2.2	−0.1	−0.7	−1.4	−0.3	−0.1	9.2	2.8	−3.9
		5.9	4.1	2.3	2.3	3.8	9.1	18.4	13.2	4.0
		9.4	7.3	8.7	4.3	9.1	19.5	35.2	24.9	22.1
5–9	59	4.4	2.9	1.3	−1.1	3.7	9.0	18.0	8.0	3.4
		9.4	7.8	5.0	2.7	8.5	17.9	29.4	18.0	9.7
		14.7	10.0	9.5	8.5	13.8	37.5	41.9	33.0	23.0
10–14	44	11.9	8.2	4.6	4.1	10.6	24.4	33.5	15.6	6.9
		16.8	12.7	9.8	8.3	18.1	37.7	42.0	21.4	12.0
		19.7	18.4	14.4	13.0	23.9	44.9	47.4	31.4	18.6
15–19	53	6.3	7.7	4.9	3.2	10.1	23.8	33.8	19.3	5.2
		11.1	9.8	8.6	8.0	16.0	39.1	44.5	29.7	14.3
		16.7	14.6	12.8	13.8	24.6	49.4	54.0	40.7	25.1
20–24	32	5.1	5.9	4.1	2.6	6.1	22.7	30.6	18.2	9.1
		10.4	8.8	8.6	8.5	15.6	38.8	44.4	33.8	18.6
		14.4	14.8	14.2	16.9	36.9	45.9	49.9	44.1	29.9
25–29	39	5.7	6.5	7.5	5.8	14.5	38.8	41.7	28.0	13.0
		11.4	12.5	12.0	15.8	22.5	44.4	47.1	35.1	26.1
		17.2	18.3	17.5	22.5	45.0	52.5	57.5	45.5	36.3
30–34	40	0.3	1.5	2.8	1.8	19.1	40.2	44.1	26.1	11.0
		5.8	6.4	7.1	10.6	39.6	50.1	48.8	39.3	22.6
		16.5	12.4	11.9	26.9	49.7	55.2	52.4	50.3	42.4
35–39	27	10.0	7.5	8.8	8.8	38.0	42.5	42.5	31.5	13.0
		15.5	15.0	15.0	12.5	48.3	51.4	50.7	40.5	31.8
		21.9	21.6	20.0	26.3	53.6	56.1	57.0	51.5	46.1
40–52	32	8.5	9.1	8.6	15.6	35.8	41.9	45.1	28.1	15.7
		11.8	14.1	14.5	24.6	45.9	50.5	50.2	38.5	22.7
		22.7	21.5	21.7	34.8	52.9	55.5	55.3	48.9	36.1

II. RESULTS

A. Noise

The preliminary survey of noise in jute processing showed a wide range of SPL values. The weaving process also displayed a range of over-all values, but these were highly dependent on loom size and type (Fig. 1). This study concerns the looms described as 43 and 63 in. in Fig. 1, which were of the narrow, flat overpick type. The weavers have been subjected to sound in the range 99–102 dB over-all SPL at the work position, measured with the slow-damping characteristic of the sound-level meter. The noise is of a wide-band continuous type (Figs. 2 and 3). Oscilloscopic examination, however, reveals transients of peak amplitude 15–18 dB above the mean noise level, because of the shuttle and picking-arm impacts. The rate of impact does not exceed 18 sec; we thus consider that weaving noise has a true impact component.[6] The transients appear to be associated with a frequency component of about 1600 cps.

B. Audiometric Data

1. Group I: Young Female Jute Workers not Regularly Exposed to Weaving Noise

The hearing levels of a group of 32 young female office employees in the jute industry were examined. Of these, 3 were excluded on grounds of ear pathology, leaving 29 subjects (58 ears). The results are expressed as mean hearing levels. These subjects, otologically normal as defined previously, were aged 18–25 years, to conform to the age range specified in the British standard[3] for normal hearing (Table I).

2. Group II: Young Female School Teachers

A sample of 25 female school teachers, aged 18–25 years, with the same otological criteria as group I, was also examined audiometrically (Table I).

3. Group III: Employed Weavers

Of the 401 weavers and retired weavers examined, the audiometric data on 150 were eliminated because of failure to satisfy the criteria for inclusion. Thus, 251 weavers remained, but in 9 of these one ear was disregarded on account of pathology, leaving a total of 493 ears. Of these, group III (employed weavers) numbered 461 ears and group IV (retired weavers) numbered 32 ears. In order to proceed to an estimate of the deterioration of hearing due to noise, we assume that (1) the hearing of our subjects was originally within normal limits and (2) in the absence of noise their hearing would subsequently have deteriorated in a manner characteristic of presbycusis. Obviously, the values for hearing levels at the different ages must be based on average values, and this must disregard individual variations. For values of hearing level at various ages, we have employed the British standard[3] for persons up to 25 years of age inclusive, and for ages above 25 years Hinchcliffe's[7] data for female ears from a random sample of a rural population in Scotland. We also assume that deteriorations of hearing due to age and due to noise are effectively separate entities,[1,8] and thus numerically additive in decibels. Thus, by subtracting from the recorded hearing level, at a particular frequency, the value of hearing level expected on the basis of age, we obtain a value in decibels, which may be

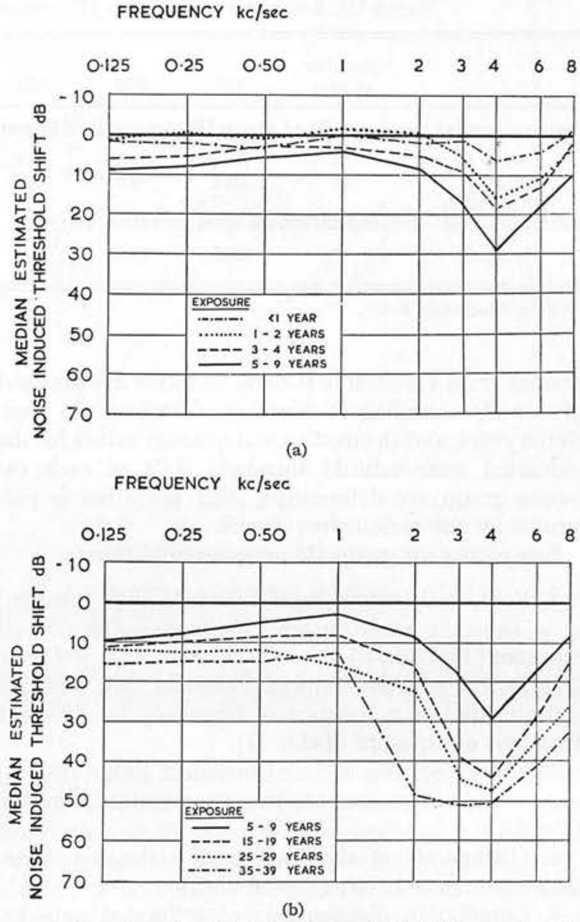

FIG. 4. Estimated noise-induced threshold shift as a function of frequency, for various durations of exposure.

presumed to indicate the degree of noise-induced hearing loss. Since factors other than noise have been as far as possible excluded, we designate the difference in decibels between measured hearing level and the appropriate presbycusis value "estimated noise-induced threshold shift." This term implies that it is not an actual measured threshold shift, in the sense of Davis, Hoople, and Parrack,[9] to whose terminology we subscribe, and that there is no implication of the degree of "permanence" of the noise-induced hearing loss, since some temporary component, although perhaps small, is almost certainly present.[10]

As an example of the derivation of estimated noise-induced threshold shift, at a particular audiometric frequency, the operation is as follows: from the recorded hearing level of each person aged 25 years of age or less is subtracted the expected hearing level derived from the British standard,[3] or, for ages over 25 years, the median values for the appropriate 10-year age

[6] H. L. Williams and A. J. Majer, 'Is it Impact or Continuous Noise?," Arch. Environ. Health **7**, 411–414 (1963).

[7] R. Hinchcliffe, "The Threshold of Hearing as a Function of Age," Acustica **9**, 303–308 (1959).

[8] A. Glorig and H. Davis, "Age, Noise and Hearing Loss," Ann. Otol. Rhinol. Laryngol. **70**, 556–571 (1961).

[9] H. Davis, G. Hoople, and H. O. Parrack, "The Medical Principles of Monitoring Audiometry," AMA Arch. Ind. Health **17**, 1–20 (1958).

[10] G. R. C. Atherley, "Monday Morning Auditory Threshold in Weavers," Brit. J. Ind. Med. **21**, 150–153 (1964).

TABLE III. Retired weavers (Group IV) compared with Hinchcliffe's age-matched rural population.

	Number of ears	125	250	500	1000	2000	3000	4000	6000	8000
		Frequency (cps)								
Hearing levels (median, dB) of group IV compared with control population										
Group IV	32	30.4	28.1	26.9	35.8	52.5	59.8	65.3	60.9	56.0
Control population[a]	47	10.1	9.6	9.7	12.8	14.6	19.8	22.2	33.9	42.2
Estimated noise-induced threshold shift (median, dB)										
Group IV		20.3	18.5	17.2	23.0	37.9	40.0	43.1	27.0	13.8

[a] From Hinchcliffe, Ref. 7.

bracket from Hinchcliffe's[7] data. Subjects are grouped (Table II) according to duration of exposure in completed years, and the median and quartile values for the estimated noise-induced threshold shift of each exposure group are determined. This operation is performed for the various frequencies.

The results for group III are presented thus:

1. Estimated noise-induced threshold shift (median) as a function of frequency, parameter duration of exposure [Fig. 4(a, b)].
2. Estimated noise-induced threshold shift (median and quartile) as a function of frequency for different durations of exposure (Table II).
3. Estimated noise-induced threshold shift (median) as a function of years of exposure, parameter frequency (Fig. 5).
4. Histograms of distribution of estimated noise-induced threshold shift (Figs. 6 and 8).
5. Cumulative distributions of estimated noise-induced threshold shift (Fig. 7).

4. Group IV: Retired Weavers

The group of retired weavers (32 ears) with mean duration of exposure of 46 years, mean age 69 years, and mean duration of retirement, i.e., freedom from weaving noise, of 6.3 years, is compared with the subjects in the 65–74 years age bracket from Hinchcliffe's[7] rural population, in terms of median hearing levels (Table III).

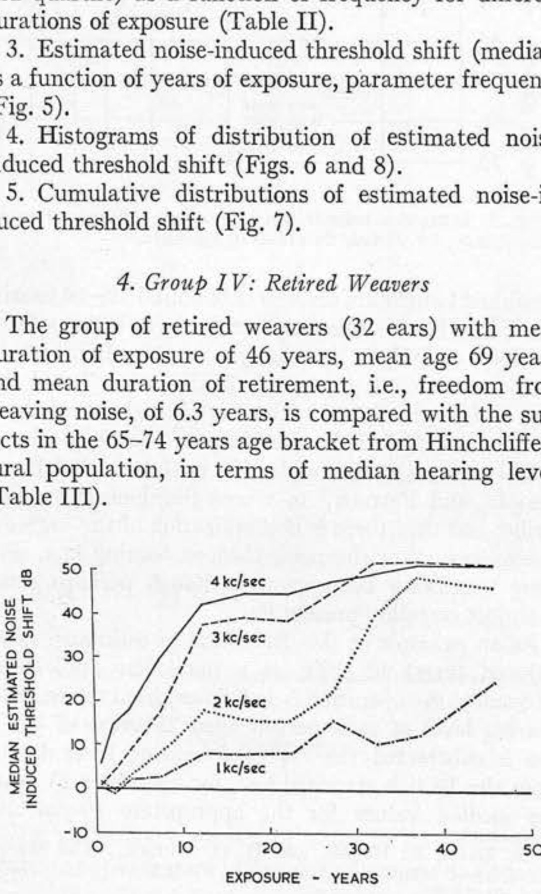

FIG. 5. Estimated noise-induced threshold shift as a function of duration of exposure.

III. DISCUSSION

The noise to which the weavers in this industry are subjected is notable for its narrow range and low variability in time and space throughout the work area. The spectrum shows maxima in the octaves centered at 1000 and 2000 cps, but the adjacent octaves are also high. The continuous nature of the spectrum by octave-band analysis is, however, deceptive; an impulsive component is present, due to reciprocating motion in the loom, and is shown fully only by oscilloscopic methods.

It has been possible to study the progress of hearing deterioration for periods of up to 52 years of exposure, because of the stable nature of the population and occupation. The thresholds of groups I and II of jute-

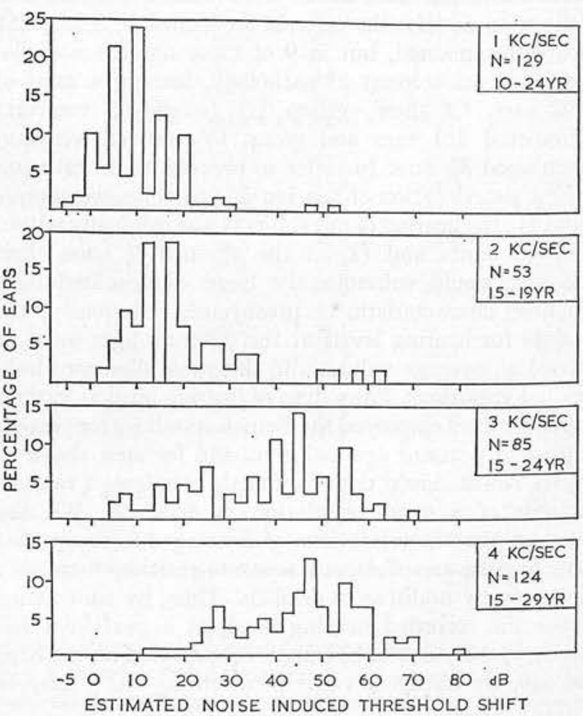

FIG. 6. Distribution of estimated noise-induced threshold shift at 1000, 2000, 3000, and 4000 cps at various durations of exposure within which estimated noise-induced threshold shift is not increasing markedly with time. Audiometer steps 2.5 dB. N: ears.

industry office workers and school teachers, respectively, are both near the audiometric zero values specified in the British standard[3] (Table I). The negative values of hearing level in school teachers are frequently encountered in young otologically normal subjects. The fact that the office workers have slightly higher hearing levels than the school teachers may be a real effect, since the former are subject to some noise in the course of occasional visits to noisier areas in the factory. The hearing levels of groups I and II establish that the audiometric conditions are such that hearing levels of the same order as those specified in the British standard audiometric zero can be realized in the audiometric vehicle.

Inspection of Fig. 4(a, b) shows that, at durations of exposure up to 2 years, the median estimated noise-induced threshold shift is not more than about 5 dB, up to and including 3000 cps, and is usually less than this, reaching about zero values.

The first and most severely affected frequency is 4000 cps, but 6000 cps is affected nearly as much at these early stages. This pattern of development is the usual one, but the depression at the lowest frequencies is striking and not easily explicable on the basis of the spectrum. The rank order of estimated noise-induced threshold shifts is related to duration of exposure, and on the whole is fairly orderly. The reason for the trend towards higher median hearing levels at the low frequencies of the group with less than 1 year's exposure compared with the 1- to 2-year group is not obvious. In view of the fairly regular complaint of marked tinnitus in the younger persons, with least durations of exposure, it is possible to speculate whether tinnitus contributed to an elevation of their auditory thresholds at these lower frequencies. The question has not, however, been further pursued.

Examination of estimated noise-induced threshold shift as a function of duration of exposure, parameter frequency, for 1000, 2000, 3000, and 4000 cps (Fig. 5), gives confirmation of previous findings[11,12] that at 4000 cps, after an initial period of increase, estimated noise-induced threshold shift ceases to grow rapidly. This stabilization occurs in this study after an interval of between 10 and 15 years, and involves the audiometric frequencies of 3000, 2000, and 1000 cps, as well as 4000 cps. Subsequent additional deterioration at 4000 cps attributable to noise is at a low rate for the next 30 years. At 3000, 2000, and 1000 cps, there is a secondary deterioration between 20 and 25 years of exposure. In the case of 1000 cps, the significance of this may be questioned, and at 3000 cps the deterioration is moderate, but, in the case of the 2000-cps frequency, it is so great (over 30 dB in 15 years) that it is extremely unlikely to be fortuitous. This resembles the findings of Nixon and Glorig,[12] and obviously will have a significant effect on the onset of social inadequacy in hearing. After an exposure duration of between 35 and 40 years, further deterioration attributable to noise ceases at 2000, 3000, and 4000 cps but persists at 1000 cps.

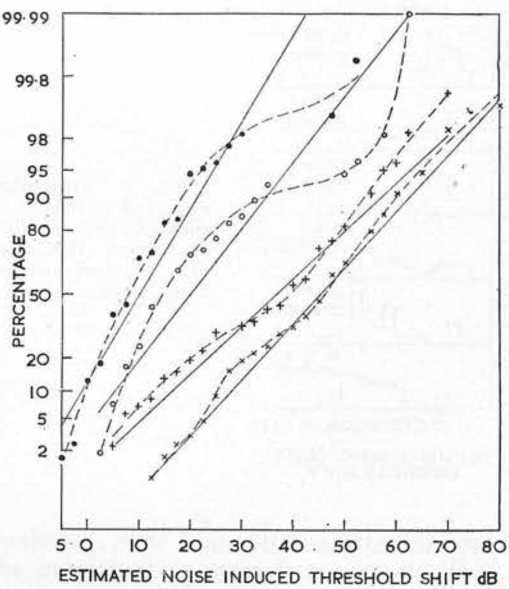

FIG. 7. Cumulative percentage distributions of data in Fig. 6. Normal distribution lines have been drawn through 50% as mean value, with slopes corresponding to the following standard deviations: 1 kc/sec = 8.57 dB; 2 kc/sec = 11.45 dB; 3 kc/sec = 15.59 dB; 4 kc/sec = 13.21 dB. •--•: 1 kc/sec. o--o: 2 kc/sec. +--+: 3 kc/sec. ×--×: 4 kc/sec. ——: Normal distribution.

A knowledge of distribution of noise-induced threshold shifts in a population is of obvious importance in hearing conservation. Median and quartile values of estimated noise-induced threshold shift for groups of subjects with various durations of exposure, as a function of frequency, are shown in Table II. There is a wide variation in the interquartile range of values at different frequencies and durations of exposure, ranging from less than 5 dB at the lower frequencies and shorter exposure durations to 30 dB at longer durations. These large interquartile values seem to be associated particularly with the 2000-cps frequency at intermediate durations (20–35 years) of exposure. The intequartile range tends to diminish, especially in the region of 4000 cps, at the longest durations of exposure. The number of ears, however, is not very large in each group, so that too much emphasis should perhaps not be put on these trends. A rigorous study of the distribution of noise-induced threshold shift would employ a population in which all the individuals had been exposed for the same duration to the same noise and were all of the same age, preferably less than 25 years so as to correspond with the age specified in accepted standards of hearing. Since this situation is manifestly unattainable, the present data have been examined for distribution of

[11] W. Burns, R. Hinchcliffe, and T. S. Littler, "An Exploratory Study of Hearing and Noise Exposure in Textile Workers," Ann. Occup. Hyg. 7, No. 4, 323–333 (1964).

[12] J. C. Nixon and A. Glorig, "Noise-Induced Permanent Threshold Shift at 2000 cps and 4000 cps," J. Acoust. Soc. Am. 33, 904–908 (1961).

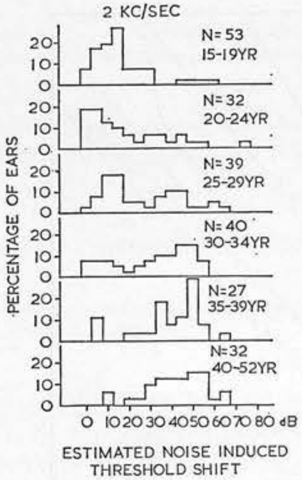

FIG. 8. Distribution of estimated noise-induced threshold shift at 2000 cps at various durations of exposure. Audiometer steps 5 dB. N: ears.

estimated noise-induced threshold shift, as defined in this study, in ranges of exposure throughout which little change has occurred (Fig. 5). By this means, the maximum number of ears is available without the undesired variable of progressive noise-induced deterioration throughout the period examined. Although the histograms show asymmetry and some isolated values, especially at 2000 cps, and the standard deviations tend to become greater with increase in audiometric frequency, there is little indication of gross departure from a normal distribution. This interpretation is supported by the appearance of the data presented as cumulative percentage distributions (Fig. 7). This shows that, if the isolated values at 1000 and 2000 cps are neglected, the cumulants tend to be grouped near the normal, especially at 3000 and 4000 cps. The implication of these isolated values is, however, obvious, in the context of hearing conservation. When the distribution at 2000 cps is examined (Fig. 8), taking all exposure-duration groups from 15–19 years up to 40–52 years, it is noticeable that the maxima and minima of estimated noise-induced threshold shift are rather similar over the whole 6 noise-exposure groups. The spread of values in certain of these groups is artificially increased by the inclusion of exposure ranges where the curves of Fig. 5 are rising rapidly, but some dispersion due to isolated values is still found, e.g., in the 15- to 19- and 20- to 24-year exposure periods, where the median is not changing appreciably with time. Some tendency towards bimodality appears in the exposure range 25–34 years, but this is in the rapidly changing range of the 2000-cps curve of Fig. 5. In any estimate of noise-induced threshold shift obtained by the method used here, the nature of the presbycusis changes in the comparison population must affect the result. In this case, it should thus be emphasized that the results are referable specifically to Hinchcliffe's[7] presbycusis data for women, but we feel considerable confidence in their use in view of their relative freedom from contamination from noise-induced hearing loss, compared with similar data for men.

The hearing of the group of 16 retired weavers (Table III) is compared with that of an age-matched population from Hinchcliffe's[7] data. Although numbers are small, the comparison does give some indication of the consequences of a lifetime of occupational exposure to this particular noise. The mean value of their median hearing levels at 500, 1000, and 2000 cps is 38.4 dB, which places them in the area of partial impairment, as defined by the American Academy of Ophthalomology and Otolaryngology. On the basis of age alone,[7] the value would be 12.4 dB. However, their estimated noise-induced threshold shift is appreciably less at 2000, 3000, and 4000 cps than in the groups of employed weavers with 35–39 years and with 40–52 years of exposure, but is more at lower frequencies. The mean duration of exposure of the retired group was 46 years, and the mean duration of retirement 6.3 years. Although conclusions cannot be drawn from the results of this small group of retired weavers, the question of what changes, if any, occur in the value of noise-induced threshold shift on cessation of the noise exposure nevertheless arises. This question must however be investigated in longitudinal studies.

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